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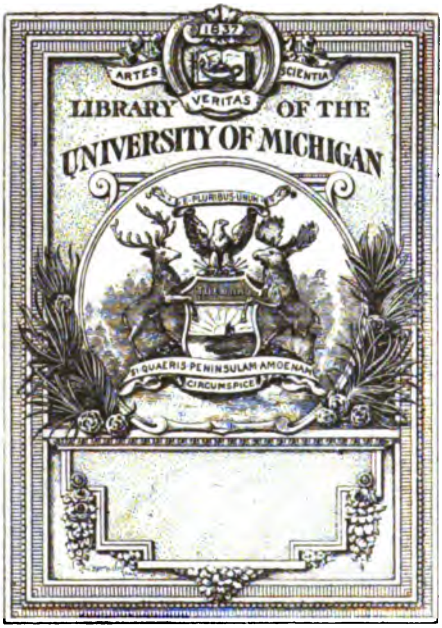
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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 141.

A. D. MELVIN, CHIEF OF BUREAU.

THE IMPROVEMENT OF THE FARM EGG.

BY

HARRY M. LAMON AND CHARLES L. OPPERMAN,
Junior Animal Husbandmen, Animal Husbandry Division.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., May 29, 1911.

Sir: I have the honor to transmit the accompanying manuscript entitled "The Improvement of the Farm Egg," by Harry M. Lamon and Charles L. Opperman, of the Animal Husbandry Division of this bureau, and to recommend its publication as a bulletin in the bureau series. In 1908 a careful survey of the conditions surrounding the egg trade was made and published as Circular 140, "The Egg Trade of the United States," wherein it was shown there was a very large loss in our annual egg output, nearly all of which was due to improper methods of handling on the farm and at the country store. A conservative estimate of this loss was given as 17 per cent of the total value, amounting to about $45,000,000 annually.

Practically all of this loss is borne by the farmers and other egg producers, and a large part of it should be easily preventable. In order to show how this loss might be prevented, the bureau last year sent the authors of the present bulletin into the State of Kansas to conduct investigations to this end. The results of the first season's work are described herein.

It is believed that Mr. Lamon, who outlined the field work, has struck the keynote in the solution of the problem by bringing about the organization of the egg buyers, with the cooperation of the State authorities, for the purpose of compelling the traders in eggs to buy on a quality basis only—in other words, to substitute the "loss-off" method of buying for the prevailing "case-count" system. Probably the best evidence that the work of the bureau in this matter had been well directed is the rapid spread of the movement into other States.

The authors desire to acknowledge the assistance of Mr. Alfred R. Lee, of the Animal Husbandry Division, who was in the field at the same time. They also wish to thank the egg merchants, railroad officials, agricultural college officers, and the State board of health of Kansas for valuable cooperation.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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DEFINITION OF TERMS USED IN THE EGG TRADE.

Candling.—The process of testing eggs by passing light through them so as to reveal the condition of the contents.

Checks.—Eggs which are cracked but not leaking.

Leakers.—Cracked eggs which have lost a part of their contents.

Dirties.—Eggs soiled with earth, droppings, or the contents of broken eggs.

Blood rings.—Eggs in which blood has developed, extending to the period when the chick becomes visible.

Floats, light.—Eggs in which embryo development has proceeded to a point corresponding to about 18 to 24 hours of normal incubation; they are not readily detected by the casual observer, even when broken.

Floats, heavy.—Eggs in which the development has proceeded further than is the case with the light floats. When broken, the yolk has a white and scummy appearance.

Rots.—A term used in the egg trade to designate eggs absolutely unfit for food purposes.

Spots.—Eggs in which bacteria or mold growth has developed locally and caused the formation of a lumpy adhesion on the inside of the shell.

Watery eggs.—Those in which the inner membrane of the air cell is ruptured, allowing the air to escape into the contents of the eggs, and giving a watery or frothy appearance.

Weak eggs.—Those in which by reason of unfavorable conditions or of age the stiffness or viscosity of the egg white is lessened, producing an egg which does not stand up well or whip into a firm froth.

Case count.—A term used in egg buying where eggs are accepted simply on the basis of number without regard to quality.

Loss off.—A term used in egg buying where eggs are tested by candling before being accepted. The bad eggs, usually the rots and broken eggs, are rejected and no pay is received for them.

Seconds.—A term often used when eggs are bought on a graded basis to designate usually the second-best grade.

Flats.—The square of strawboard which is placed between layers of eggs in the egg case.

THE IMPROVEMENT OF THE FARM EGG.

INTRODUCTION.

It is an accepted fact that the commercial egg of this country is of a very poor quality, and when the housewife purchases eggs of the local grocer she is often compelled to break them first in a saucer before using them for culinary purposes. This poor quality in eggs has been attributed by the majority of persons to the retention of the eggs in cold storage until a large per cent of them are unfit for human consumption. This condition, however, is not as a rule due to cold storage, but to the condition of the eggs when they go into storage. If eggs are full and fresh when put into a well-equipped and properly managed cold-storage house there is, practically speaking, no change in quality during the period they are normally held which renders them unfit for food. On the other hand, if eggs are heated, shrunken, watery, or otherwise deteriorated when they reach the storage house, they can not improve in quality by virtue of being held at a low temperature and are quite likely to deteriorate to a still greater extent. In other words, the function of cold storage in the case of eggs is to retard or prevent changes which are unfavorable to good quality.

From the time the eggs reach the poultry packer or other large buyer of eggs they are as a rule given good care, and the deterioration from this point until they go into cold storage or reach their ultimate market is comparatively small. While there is, undoubtedly, still room for improvement during this period of the egg's journey to market, conditions are on the whole too satisfactory to account for the very serious deterioration which is so widespread and marked.

It is therefore necessary to go further back in the process of marketing and to study the conditions surrounding the production and handling of eggs from the farm to the packing house, if a really noticeable and substantial improvement is to be effected. The Bureau of Animal Industry has undertaken to grapple with this problem and a report of the preliminary work was published in 1909, as Circular 140, entitled, "The Egg Trade of the United States." This circular gives a bird's-eye view of the situation in all sections of the country and forcibly demonstrates the need of procuring more detailed information on this subject.

The work described in the present paper deals mainly with the situation in the Middle West and particularly in the State of Kansas. The objects sought to be attained are, to improve the quality of commercial eggs by investigations on the ground to determine the reasons for the poor quality of eggs so frequently seen, to devise methods for improving the present conditions economically and reduce the loss to a minimum, and, by a campaign of education, to disseminate the results of the investigation in other sections of the country where similar conditions prevail in the egg trade. The loss represented by improper handling of eggs on the farm and in the country store is, in the main, a preventable one. It is borne directly both by the producer and the consumer, and affects the consumer also by curtailing the egg supply of the country as well as by lowering its quality. By preventing this loss it is possible for the farmer to realize a greater profit and for the consumer to be more certain that he is purchasing eggs of reasonably good quality.

EXTENT OF THE INDUSTRY.

There is probably no other domestic animal which has a more general distribution than the hen, and the part which she plays in the agricultural wealth of this country is almost incredible. According to the most recent statistics of the Department of Agriculture, the products of the American hen aggregate a total value of more than $620,000,000 annually. This sum is stated to be equal to the value of the hay crop for 1908 and greater than the combined value of oats and potatoes for the same year. It is nearly nine times the value of the tobacco crop and equal to that of wheat.

Poultry and eggs are produced in all sections of the country, but the business finds its greatest scope in areas presenting the most favorable conditions. It is a noticeable fact that the bulk of these important products is produced on the farms of the Mississippi Valley. In this section there are practically no large intensive poultry farms such as are commonly found in the Eastern States and on the Pacific coast. Poultry keeping, therefore, is largely incidental, the hens being considered and treated largely as an agency for converting material which would otherwise go to waste into a salable product. Consequently the poultry and eggs produced constitute merely a by-product of the general farm. Because prices for poultry products are comparatively low the farmers make no effort to keep larger flocks than can be supported by this waste without much attention or extra feed, and because individual flocks are small little attention or thought has been given to improving the product or the method of disposing of it. It should be kept in mind, however, that while individual sales of poultry products are small, the aggregate for the year is large, reaching for each State in the Middle West a total of many millions of dollars.

LOSS DUE TO POOR HANDLING.

The estimate of the author of Circular 140 of this bureau places the annual loss for the entire country at 17 per cent of the total value of the crop, or $45,000,000 annually. A vivid idea of what this loss means to the State of Kansas alone may be obtained from the following statement contained in a circular letter distributed by the packers and car-lot shippers of that State:

> It is the belief of those who are in a position to know that the value of the egg product of the State of Kansas would be increased approximately $1,000,000 annually if proper care were taken of the product by the farmer and merchant.

More accurate figures show that the loss varies during the year from 5 to 25 per cent, depending largely on the time of year and weather conditions.

The following table gives a condensed report of the total receipts of three Kansas egg buyers during the months of July, August, and September, 1910, showing the number of rots thrown out as the result of candling as well as the number of seconds and checks in two instances:

TABLE 1.—*Showing loss in eggs received by three Kansas buyers in summer months of 1910.*

Month.	Locality.	Total receipts.	Firsts.		Seconds.		Checks.		Rots.	
		Dozens.	*Dozens.*	*P. ct.*	*Dozens.*	*P. ct.*	*Dozens.*	*P. ct.*	*Dozens.*	*P. ct.*
July	A	223,230	207,240	92.9					15,990	7.1
	B	100,899	60,644	60.2	27,900	27.6	5,057	5.0	7,298	7.2
	C	36,600	28,970	79.2	5,136	14.0			2,494	6.8
August	A	160,320	133,620	83.5					26,700	16.6
	B	71,430	45,055	63.1	17,265	24.1	3,503	4.9	5,607	7.8
	C	46,500	31,151	67.0	8,997	19.3	1,978	4.2	4,374	9.4
September	A									
	B	42,710	29,659	69.5	8,460	19.8	2,063	4.8	2,508	5.8
	C	24,880	17,260	69.4	5,253	21.1	889	3.5	1,478	5.9
Total		706,569	553,599	78.3	73,011	10.3	13,510	1.9	66,449	9.4

It will be seen by an examination of the above table that the total receipts of the three localities were 706,569 dozen. At 15 cents a dozen, which is about the average price for "firsts" during the months of July, August, and September, the value of the total receipts would be $105,985.35. However, 152,970 dozen, or 21.7 per cent, of these eggs did not pass as "firsts." Of this number 86,521 dozen were classed as seconds (which includes checks), and 66,449 dozen were "rots." It will be noticed that locality A does not discriminate against seconds and checks. This condition makes the actual loss in seconds and checks less than it would be under the candling system of localities B and C. The per cent of "firsts" is also necessarily greater. When buying on a loss-off basis the price paid for seconds is from 1 to 8 cents per dozen less than the price of firsts. At 6 cents this would mean a loss of $5,191.26 in localities B and C. The 66,449 dozen " rots " represent a loss of $9,967.35. Thus there is from eggs thrown out and from those depreciated in quality a total loss of $15,158.61, or 14.3 per cent of the original value, and this does not include the possible losses from seconds and checks in locality A.

The following table, giving the weekly receipts of still another buyer, shows the percentage that were classed as " firsts " during the months of June to October, 1910, inclusive.

TABLE 2.—*Percentage of eggs classed as firsts in weekly receipts of one buyer.*

Week beginning—	Percentage of firsts.	Week beginning—	Percentage of firsts.	Week beginning—	Percentage of firsts.	Week beginning—	Percentage of firsts.
June 4	94.13	July 16	80.88	Aug. 27	83.68	Oct. 8	91.88
June 11	88.31	July 23	80.57	Sept. 3	83.11	Oct. 15	91.44
June 18	86.43	July 30	63.68	Sept. 10	88.64	Oct. 22	94.24
June 25	84.15	Aug. 6	66.53	Sept. 17	86.75	Oct. 29	91.25
July 2	80.00	Aug. 13	87.75	Sept. 24	86.82		
July 9	85.82	Aug. 20	87.71	Oct. 1	91.66		

The figures given above are based on an average weekly business of 15,000 dozen eggs. The decline in quality with the increased severity of the summer heat can be readily traced. This decline reached its maximum during the last week of July and the first week of August, when the weather was unusually warm. After this time the number of eggs classed as " firsts " rapidly increased. It should be kept in mind, however, that in classing these eggs as " firsts," practically all except " rots," spots, blood rings, badly heated eggs, and broken eggs were included. The apparent improvement does not, therefore, indicate that there had been any improvement in shrunken eggs or others less badly deteriorated.

These two tables show a serious condition, which, moreover, is not limited to the particular cases specified, but is widespread and common. Under the case-count system of buying the producer stands this loss, although, as will be explained later, he does not realize it. How much better it would be for a system of marketing to be brought into general use which would make him realize this loss directly and thereby provide an incentive to market his eggs in a more careful and rational manner. The so-called " loss-off " is such a system. Needless to say a strong effort is being made by this bureau to encourage the introduction of this system.

FACTORS INFLUENCING QUALITY IN EGGS.

THE CASE-COUNT SYSTEM OF BUYING.

Viewed from the standpoint of progress and the improvement of the poultry industry of the Middle West, the system of marketing in general use in this great producing section known to the trade as the "case-count" system has proven a great stumbling block. It is a system of payment for number alone regardless of quality, and in consequence it has not only not provided an incentive for care and attention to quality, but by neglecting to reward carefulness has even encouraged careless and dilatory marketing on the part of farmers, with the attendant loss in quality. Briefly, case-count buying consists of the payment of the fixed price which happens to be current at the time for each and every dozen eggs which may be offered for sale, regardless of whether the eggs themselves are good, bad, or indifferent. The only requisite in most cases to consummate a sale is for each egg to have an intact shell. The case-count system of buying eggs may, therefore, be said to be the greatest factor in preventing an improvement in the general quality of commercial eggs. No more practical step can be taken, or one which would have a more immediate and far-reaching effect in improving the quality of the eggs of the Middle West, than to discard this system of buying and to replace it by the one known to the trade as "loss-off," in other words, to buy on a candled or quality basis.

THE LOSS-OFF SYSTEM OF BUYING.

Where this system is in use the eggs as bought are "candled," that is, subjected to a test which shows quite definitely their condition and quality. Candling is performed by holding the eggs up to a small hole, about the size of a half dollar, cut in a shield of metal or other material, behind which is a strong light. Usually this light is furnished by an ordinary 16-candle power incandescent light, but a lamp, candle, or even the sunlight may be utilized. The person candling the eggs is in a dark or semidark room, so that the light shines through the eggs, and when the latter are twirled the condition of the contents is at once revealed to an expert eye. By this test it is possible to detect rots, spots, and other deteriorated eggs, such as shrunken, weak, watery, and heated eggs. In paying for eggs bought on this basis, the rots and usually the spots and blood rings are thrown out entirely, so that they become a dead loss to the person responsible for them. Often in buying from the farmer no other distinction is made. The eggs are simply divided into two classes, one of which is good enough to accept and pay for while the other is rejected and payment therefor is refused. Such a classification is a distinct step forward and results in a great improvement in the eggs. Indeed, there are many reasons to believe that such a simple system is preferable when dealing with the farmers to a more complicated one where the eggs are placed in several grades, according to quality, and for which different prices are paid. In the latter case the farmer is prone to think that he is being cheated if a part of his eggs are accepted but bring a less price than the others.

The agency indirectly responsible for the opposition to this method of buying and for the continuance of the case-count system is the country store.

THE COUNTRY STORE.

It has been the custom from the time towns were settled throughout the West for the country store to handle the eggs in most instances.

The peculiar workings of this system, together with its baleful effects, have been well discussed by Milo M. Hastings in Circular 140 of this bureau. He says:

> The trips to the general store, necessary to supply the household needs, offer the most convenient opportunity for this marketing; but there is a reason for the general merchant being an egg buyer that is more interesting and far-reaching in its effect upon the egg trade. The merchant buys eggs because by doing so he can control his selling trade. There are two reasons why the farmer trades where he sells his eggs: (1) Because it is convenient to trade at one place, and (2) because he wishes to avoid offending the merchant, which he would do if he broke the established custom of trading out the amount.
>
> The merchant knows that to buy eggs means to sell goods, and he therefore bids for eggs. His competitors in the same town, as well as in other towns, also bid for eggs. The effect to the merchant of lowering the price of his goods or raising the price of eggs is financially the same. In either case it is the matter of cutting prices under the spur of competition. Now, the articles on which the merchant makes his chief profits are dry goods and notions. Such articles are not standardized, but their real value varies in a manner quite impossible of estimation by the unsophisticated. On the other hand, eggs are quoted by the dozen, and all who run may read.
>
> Suppose, for illustration, two merchants in the same town are each doing business with a 20 per cent profit and are buying eggs at 10 cents and selling for 11, the 1 cent advance being sufficient to pay for the labor of handling, incidental loss, and a small profit. One merchant concludes to cater for more trade. If he marks his goods down he will gain some extra trade, but people will fear his goods are cheap. But let him put out a placard " Eleven cents paid for eggs," and the farmers will throng his store and be less inclined to question the quality of his goods. This move having been successful, his rival across the street quietly stocks up with a cheaper line of dry goods, and one fine morning puts out a card, "Twelve cents paid for eggs," and more farm wagons will be hitched on his side of the street. The volume of business at the lower profit being insufficient to maintain two men in the town, a mutual understanding is gradually brought about by which the prices of goods sold are worked back to the basis of 20 per cent gross profit, but the false price of eggs serves to draw trade from neighboring towns, and is maintained at the higher level.
>
> As a matter of fact the price paid to farmers for eggs by the general stores of the Mississippi Valley is frequently 1 to 2 cents above the price at which the storekeeper sells the product. Allowing the cost of handling, we have a condition prevailing in which the merchant is handling eggs at from 5 to 10 per cent loss, and it stands to reason that he is making up the loss by adding to the prices of his goods.

Some of the effects of this system are:

1. The inflated price of merchandise is an injustice to the townspeople and to farmers not selling produce; in fact, it amounts to a taxation of these people for the benefit of the egg producers.
2. The inflated prices of the merchant's wares work to his own disadvantage in competition with mail-order or out-of-town trade.
3. The farmer who exchanges eggs for dry goods is not being paid more for his eggs, save as the tax on the townspeople contributes a little to that end, but is in the main merely exchanging more dollars.
4. The use of eggs as a drawing card for trade works in favor of inferior produce, and the loss to the farmer through the lowering of prices thus caused is much greater than his gain through the forced contributions of his neighbors.

DELAY IN MOVING EGGS.

The delay which takes place from the time the eggs are produced on the farm until they reach the packing house or car-lot shipper is a direct result of the case-count system of buying. This delay is most serious, and, coupled with weather conditions, it is responsible for the changes occurring and the loss and deterioration caused. Incidental to the delay and the ignoring of the necessity for good quality, many careless habits develop in handling the eggs. On the farm this usually takes the form of negligence in gathering the eggs, also in storing them in hot, damp, or other unsuitable places, and in holding them for a considerable length of time, either because it is not convenient to go to town or, in the fall on a rising market, with the idea of getting a better price. At the country store, also, the eggs are often held for a considerable length of time. When the eggs finally reach the packer they may, therefore, be several weeks old, and as they are subjected to high temperature during the summer and early fall months, and may have been held in damp places, changes often take place which bring them under one or other of the following well-recognized classes.

CLASSES OF DETERIORATED EGGS.

HEATED EGGS.

Heated eggs occur most commonly, of course, during the summer months. They are caused by the development of the embryo in fertile eggs. Whenever a fertile egg is subjected to proper conditions of heat and moisture, whether it be under a hen, in a bucket behind the kitchen range, or in an egg case in the hot sun on the railroad station platform, the embryo development proceeds. The degree to which this development has progressed will determine into which of the classes or grades recognized by practical egg men it will fall. "Light floats" are those in which there is only a slight development, approximately equal to that reached at the end of 18 or 24 hours of natural incubation. Usually this development would go unnoticed when the egg is broken. "Heavy floats" show a greater development, usually sufficient to be noticed on breaking. "Blood rings" are characterized by the appearance of a ring of blood next to the shell membrane. In these eggs the developing embryo has died, and the peripheral blood vessel has adhered to the membrane and is plainly visible before the candle. In other cases the development proceeds until the growing chick is visible before the candle. Many of the eggs that contain well-developed chicks are classed as rots. In exceptional cases the development may proceed until the egg actually hatches in the egg case or wherever else it may be.

HELD OR SHRUNKEN EGGS.

The contents of a fresh-laid egg completely fill it, but as the egg cools the contents shrink slightly, causing a small bubble or air cell to appear at the large end. As the egg grows older the water is continually evaporating from the white through the shell membrane and the shell, and this causes the air cell in the large end of the egg to increase in size. Such an egg is characterized as held, or shrunken. The rapidity with which this evaporation and shrinking progresses depends, of course, upon the humidity of the air surrounding the egg. Shrunken eggs are most common during the fall and early winter, when the price of eggs is rising. At this time both the farmer and the storekeeper are often guilty of holding eggs in the hope that the price will have advanced by the time they are ready to sell. Needless to say, they largely defeat themselves, for buyers have learned to anticipate this condition, and consequently depress the price below what it would otherwise be.

ROTS.

A number of different kinds of rots are recognized by the trade, but the two most common classes are those known as black or mixed rots and as spot rots or spots. The black rot is often caused by bacterial growth. These eggs appear dark or black before the candle and are characterized on breaking by a most offensive odor. In the case of spot rots, the bacterial growth has remained localized and shows as a spot or patch next the shell and usually attached to it. These are easily detected on candling. Spots are also often caused by the development of molds.

DIRTY EGGS.

Many eggs are soiled and dirty. These are caused by dirty nests, thus allowing the eggs to be soiled by droppings, by dirt from the feet of the fowls, particularly during rainy weather, and by smearing with the contents of broken or cracked eggs.

BROKEN EGGS.

Many eggs are cracked or broken before reaching the packing house. Those cracked only slightly, so that the egg contents do not leak out, are known as "checks." Those in which the egg contents are leaking or have partially leaked away are known as "leakers." Broken or "checked" eggs depreciate rapidly and must, therefore, be separated out and sold for immediate consumption at a reduced price or they must be dried or broken out in cans and frozen.

OTHER DETERIORATED EGGS.

As eggs are very prone to take on the taste and odor of their surroundings, a considerable number deteriorate in this respect. If stored in damp cellars, they are likely to develop a musty flavor which is practically impossible to detect without tasting. Other flavors caused by storing with vegetables, such as onions, are common.

METHODS USED FOR THE IMPROVEMENT OF THE FARM EGG.

In attacking this problem the bureau concentrated its efforts upon those measures which were considered the most important and gave promise of accomplishing the most good. The two main lines were: First, the encouragement of the loss-off system of buying, and second, a close and careful examination of the conditions surrounding the marketing of eggs all the way from the producer to the packing house. The State of Kansas was selected as a working base for three reasons: First, the output of eggs is enormous, but the quality has usually been low. Second, the buyers of the State had already made at least one attempt to enforce the loss-off system of buying, which indicated a receptive spirit on their part. Third, the statutes of Kansas contain provisions giving the State board of health abundant authority to prevent the sale of bad eggs within the State.

The first attempt, above alluded to, of enforcing the loss-off system of buying failed because the buyers along the borders of the State met competition from adjacent States where the case-count system was in operation and, becoming discouraged, in self-defense resorted again to the case-count system. The other buyers of the State in turn felt compelled to return to the case-count basis, and the entire agreement soon fell to pieces.

ORGANIZATION OF BUYERS.

The first step, therefore, was to get the buyers together. With the cooperation of officers of the State board of health and the Kansas State Agricultural College, a meeting of the Kansas Carlot Egg Shippers' Association was held at Topeka on June 10, 1910, where an agreement was entered into to buy strictly on a loss-off basis after July 1, 1910.

The proceedings of the meeting resulted in the adoption of the following resolutions:

First. That Dr. Crumbine have cards and circulars printed and mailed to every merchant that handles eggs in the State of Kansas, the association bearing the expense.

Second. That buyers send out circulars to their patrons, through their offices, relative to their attitude on the marketing of eggs.

Third. The term designating loss-off includes all rots, spots, blood rings, and leakers.

Fourth. That Dr. Crumbine and G. C. Bowman shall draft and have printed circulars to be sent to shippers for distributing to their patrons.

Fifth. That buying on a loss-off basis shall commence July 1, 1910.

Sixth. That the members of the association shall sign the following agreement:

"We the undersigned egg shippers, hereby agree that from and after July 1, 1910, we will buy all eggs loss-off, said loss-off to include all rots, spots, blood rings, and leakers."

The following circular was drafted and mailed by members of the association to the dealers throughout the State from whom they drew their supplies.

TO OUR PATRONS.

The prices current on Kansas eggs on the eastern market indicate that the Kansas egg has a "bad name." This deplorable condition is the natural and inevitable result of buying and shipping eggs by the "case-count" system, or, as one man graphically expressed the situation, "everything with a shell goes in Kansas." This lowered price of the Kansas product means a great loss to the producers and buyers of a wholesome article, which can never be remedied until the egg unfit for food is eliminated from the channels of trade. It is the belief of those who are in a position to know that the value of the egg product of Kansas would be increased approximately $1,000,000 annually if proper care is taken of the product by the farmer and merchant.

An egg that will grade a first or extra when delivered by the farmer will rapidly deteriorate into a second or even a third if held for only a short time during the heat of summer. Therefore, the farmer should gather his eggs at least twice a day, put them in a cool place, and deliver them to the merchant at least every second day, and the merchant in turn ship daily during the hot season.

We desire also to call your attention to the fact that the Government has shown considerable activity of late in the seizure of the eggs entering into interstate commerce which have not complied with the national food and drug law in that there were many of them unfit for food.

The State authorities, cooperating with the Federal Government, are insisting that the sale of eggs unfit for food shall cease. There is only one method of bringing about the results above indicated; namely, that of buying "loss off." By putting into action the above suggestions, in handling and carefully candling, it has been agreed that beginning July 1, 1910, all eggs shall be purchased on the "loss-off" basis.

We want every merchant to cooperate with us by candling all eggs and ship them daily, and further, instruct the producers to gather eggs at least twice a day, put them in a cool place, and market them every other day.

COOPERATION OF STATE OFFICIALS.

Profiting by the failure of the former attempt to bring about the loss-off system of buying, the support of the State board of health was early enlisted in the cause. This was an important step, without which the movement would have met the same fate as its predecessors, for the activity of the State board of health served to keep wavering buyers in line through fear of prosecution for handling bad eggs. It is a pleasure to state that the secretary of the board, Dr. S. J. Crumbine, was most active in supporting the movement and lent the force of his department to its successful operation. Placards (as below) were printed and posted in about 3,000 stores throughout the State where eggs were bought or sold.

> WARNING—BAD EGGS.
>
> ---
>
> The Kansas food and drugs law forbids the sale or offering for sale of eggs unfit for human food. "Sec. 7. Subdivision sixth: If it consists in whole or in part of a filthy, decomposed, tainted, or putrid animal or vegetable substance," etc.
>
> Reg. 11, Par. C: "The sale, keeping for sale, or offering for sale of tainted or rotten eggs is prohibited."
>
> *Inspectors of this department, and all police officers of the State, are instructed to enforce these provisions of the law.*
>
> KANSAS STATE BOARD OF HEALTH,
> By the Chief Food and Drug Inspector.
>
> TOPEKA, KANSAS, June 11, 1910.

INVESTIGATION OF CONDITIONS SURROUNDING THE EGG INDUSTRY.

After the above buying agreement had been accomplished, and the assistance of the State authorities assured, the efforts of the bureau were at once directed to a comprehensive study of the conditions in the field and a campaign of education was immediately begun among the Kansas farmers. The following account of the methods used in making this study may serve as a guide to similar work which may be undertaken in other States.

As the first step, a packing house was selected whose manager was in sympathy with and believed in the practical good to be accomplished by such a study. The association with such a packing house made it possible to investigate shipments of eggs, whenever desired, from their origin on the farm, and to observe the changes which might occur. By virtue of enjoying the confidence and friendship of the manager, it was also possible to get into touch with some of the smaller buyers and stores shipping eggs to him. Through these buyers and storekeepers it was again possible to make the acquaintance and secure the confidence of the farmers furnishing them with eggs. Thus a complete chain was established from the farm to the packing house, all parts of which had a direct interest in the egg business, and all of which were willing to give the bureau any help possible. The conditions found as a result of these studies are given in the following section.

CONDITIONS ON THE FARM.

The writers made personal visits to more than 100 farms during the summer of 1910, driving more than 1,000 miles over the country roads. Detailed records are available for 92 of these farms. In assembling the information secured the card shown below was used.

[Front of card.]

[UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF ANIMAL INDUSTRY.]

POULTRY AND EGG MARKETING INVESTIGATIONS.

FARMER'S CARD.

No. ____________

Name ____________
Address ____________
Date ____________
Character of farm:
    Size ____________
    Crops raised ____________
    Stock kept ____________
Poultry accommodations:
    Houses—
        Kind ____________
        Number ____________
        Location ____________
    Nests—
        Kind ____________
        Number ____________
        Location ____________
    Runs—
        Size ____________
        Number ____________
        Treatment ____________
Poultry kept:
    Variety ____________
    Number—
        Males ____________
        Females ____________
        Ages ____________
Natural or artificial incubation ____________
Natural or artificial brooding ____________
Egg production:
    Weight of eggs per dozen ____________
    Method of feeding ____________
    Rations ____________
Gathering eggs:
    Frequency ____________
    By whom ____________
    In what ____________
Keeping eggs for market:
    Where ____________
    How long ____________
    Temperature ____________
How marketed ____________
Distance from market ____________
Name and address of person or firm to whom sold ____________

[Back of card.]

SCORE CARD OF FARM POULTRY FLOCK.

Equipment.	Score. Perfect.	Score. Allowed.
POULTRY STOCK.		
Health	10	
Vigor	10	
Pure breeding	5	
Age	3	
All in first or not over half in second laying year necessary for perfect score.		
HOUSES.		
Location	7	
Well drained 5		
Southern or southeastern exposure 2		
Construction	5	
Tight back wall, ends, and roof 1		
Dry floor 2		
Economy 1		
Location and shape of windows 1		
Light	3	
One square foot of glass to 12–16 floor space or 1 square foot of glass, and 1 square foot of cloth to 25 feet floor space.		
Ventilation	3	
Open front or curtain front 3		
Adjustable windows 2		
Floor space	3	
4.5 to 6 square feet per hen 3		
3.5 to 4.5 square feet per hen 2		
2.5 to 3.5 square feet per hen 1		
Less than 2.5 square feet per hen 0		
Convenience	1	
Nests	1	
1 to 5 hens.		
Cleanliness	5	
Frequent removal of droppings 2		
Nests 2		
Walls, windows, etc 1		
RUNS OR RANGE.		
Square feet per bird	3	
100 to 200 square feet 3		
50 to 100 square feet 2		
Less than 50 square feet 1		
No run 0		
Cultivation	4	
Drainage	2	
Shade	1	
Total	66	

Methods.	Score. Perfect.	Score. Allowed.
FEEDING.		
Water: Clean, fresh, abundant	3	
Variety of feed	5	
Green feed	2	
In winter and at other times when not available.		
Meat feed, wholesome	3	
Grit	1	
Shell	1	
Fresh feed, not sloppy or sour	1	
Sound feed	1	
HANDLING EGGS.		
Gathering: Once daily, twice in hot weather	3	
Keeping eggs	4	
Cool, 50° to 70° F 1		
Dry, to prevent mold 1		
Free from contamination of taste or odor 1		
Clean surroundings 1		
Frequency of marketing	3	
Daily 3		
Semiweekly 2		
Weekly 1		
Less often 0		
Grading out odd-sized, dirty, washed, cracked, and doubtful eggs for home use	4	
Separation of males from females during warm weather after breeding season	3	
Total	34	

Equipment.............. + Methods.............. = ...**Final Score.**

This card was found to be a most convenient method of tabulating and preserving the data secured from individual farms. The score card on the back served to make comparison easy by placing a numerical value on the poultry equipment and methods.

Before entering into the discussion relating to the poultry conditions on the farm, it might be well to give a brief description of the size and general character of the farms which were visited. As to size, there are in Kansas the smaller farms containing from 60 to 300 acres and also those which are several thousand acres in extent, the latter being used for the most part as pasture and grain land, while on the former diversified farming is the usual practice. The principal crops raised are corn, wheat, oats, barley, kafir corn, millet, sorghum, potatoes, and hay. The term "hay" would include many varieties of cultivated grasses and legumes, and of these alfalfa is by far the most important crop. The classes of live stock which are raised extensively are horses, beef cattle, milch cows, sheep, and hogs, beef cattle and hogs being in the majority. The large farms, or ranges, do not as a rule have any great number of poultry on them, and consequently play a small part in the present discussion. From this general description it is easy to understand why poultry forms an important part in the agricultural wealth of this section of the country, since grain and other desirable feed, including alfalfa, are abundantly and economically raised, and the soil and climatic conditions are well suited to the production of poultry. The details of the 92 farms previously referred to in regard to acreage and size of flocks are as follows:

TABLE 3.—*Relation of size of farm to number of hens kept, based upon 92 Kansas farms.*

Size of farm.	Number.	Total acreage.	Average acreage.	Total number of hens.	Average number of hens.	Hens per acre.
80 acres or less	18	1,440	80.0	1,998	111.0	1.39
81 to 160 acres	45	6,514	144.7	5,401	120.0	.83
161 to 240 acres	18	3,828	212.7	2,190	121.7	.57
Over 240 acres	11	3,805	345.9	1,680	152.7	.44
Total	92	15,587	169.4	11,269	122.5	.72

THE POULTRY STOCK.

The value of purebred poultry has not been realized to as great an extent by the farmers of Kansas as it should be. The bulk of the poultry on the farms are what are commonly known as mongrel or dunghill fowls. When any breeding is apparent Barred Plymouth Rock and Leghorn characteristics predominate. A small proportion of the farmers, however, do keep some purebred poultry. In Plate I is shown a view of a good farm flock of Rose Comb Rhode Island Reds. The breed most popular among farmers is the Barred Plymouth Rock.

Improvement is usually sought by bringing in fresh blood every two or three years in the form of a new male bird, generally of a different breed each time. About the only visible effect of this spasmodic scheme is to add yet greater dissimilarity to the already wonderfully variegated flock. If the farmer would carefully select 10 or 12 of his best females each year and mate them with a purebred male which conformed to the general character of the females, adhering always to the same breed, he could in the course of a few years make a marked improvement in his flock.

The introduction of Leghorn blood (and many farm flocks show some trace of Leghorn blood) has had a marked tendency to decrease the size of the average farm fowl in Kansas. This point was forcibly demonstrated to the authors by observing the weights of many thousands of birds in the large packing houses, and also by weighing eggs from the flocks of all the farms visited. These observations showed that the average weight of hens on the farm ranged from 2½ to 4 pounds, and the average weight of eggs per dozen was 23 ounces. At a glance it is quite evident that the weight of the mature fowls is very much lower than it should be, and observations have shown that the average weight of a dozen eggs from purebred stock does not fall below 24 ounces. The standard weights of the popular general-purpose breeds are given below:

Plymouth Rocks (6 varieties): Hen, 7½ pounds; cock, 9½ pounds.
Wyandottes (8 varieties): Hen, 6½ pounds; cock, 8½ pounds.
Orpingtons (3 varieties): Hen 8 pounds; cock, 10 pounds.
Rhode Island Reds (2 varieties): Hen, 6½ pounds; cock, 8½ pounds.

While it is quite evident that the stock on the farms in this section is undersized, and that the eggs are smaller than those of purebreds, it is satisfactory to note that there is a tendency at the present time to improve this inferior stock or discard it entirely by purchasing eggs or stock of some breeder who handles a pure breed of the general-purpose type. One of the reasons for this change is that many of the large packing houses are offering 2 to 3 cents more per pound for market fowls of the heavier breeds than they are for the Mediterranean or lighter breeds. The following table shows the breeds of poultry kept on the 92 farms where detailed studies were made, and the relative proportion of purebred flocks and flocks of mixed breeding:

TABLE 4.—*Breeding of chickens kept on 92 Kansas farms.*

Purebred flocks.			Flocks of mixed breeding.		
Breed.	Number of farms.	Per cent of total.	Breed predominating.	Number of farms.	Per cent of total.
Plymouth Rock	4	4.3	Plymouth Rock	44	47.8
Leghorn	5	5.4	Leghorn	13	14.1
Rhode Island Red	2	2.2	Rhode Island Red	4	4.3
Orpington	1	1.1	Orpington	4	4.3
Wyandotte	4	4.3	Wyandotte	2	2.2
Langshan	2	2.2	Brahma	2	2.2
			Minorca	1	1.1
			Plain mixed	4	4.3
Total	18	19.5	Total	74	80.3

POULTRY BUILDINGS.

The majority of the farm poultry buildings are either poorly constructed for the purpose, or were buildings which had formerly been used for other purposes. There is little indication of any special effort on the part of the farmer to provide clean comfortable quarters for his fowls. He seems to take it for granted that the fowls, unlike the horses and cattle and other live stock, do not require comfortable quarters in order to be profitably maintained. In this assumption he is partially correct, for where there is very little investment and a more or less regular income he is sure to realize some profit. It is, in fact, almost impossible to neglect fowls to such an extent that they are maintained at a loss under such conditions. Even in instances where the farm flock is compelled to roost in the trees throughout the entire year, and forage for the greater part of their feed, some profit is usually realized. All this is true because the fowls, on account of this hardy outdoor existence, are as a rule in excellent health and produce enough eggs in the spring and summer months to return a reasonable profit to the farmer.

Views are reproduced in the upper portion of Plate II, showing two extreme types of poultry houses, the one poorly and the other well constructed. Both houses provide comfortable quarters for the fowls in so far as protection from the weather is concerned, but when we consider the question of eradicating disease, lice, or mites, the building shown in figure 1 presents a difficult problem. It is true that for all practical purposes the building in figure 2 does not afford any better protection from the weather elements than the inferior house, but the material and workmanship is such that diseases and vermin can be successfully combated. The most serious objection to this house is that it is a more expensive structure than many farmers would care to erect. There is, however, no necessity for going to one extreme or the other, and in figure 3 is shown what can rightly be called a happy medium. This house combines the good points of both the others, and the material and workmanship is such that it is as easy to keep in a sanitary condition as the more expensive house.

CLEANLINESS AND VENTILATION.

A not uncommon practice on Kansas farms is to clean the poultry house only once or twice a year and the result is that many of the houses are in a very filthy condition. The accumulation of filth and droppings on the floor of the poultry houses, 95 per cent of which have dirt floors, opens the way for the invasion of many infectious diseases, and the droppings from one sick fowl may be the means of infecting the entire flock. In one or two instances the houses were equipped with a dropping board under the roosts. This practice is

A FARM FLOCK OF RHODE ISLAND RED CHICKENS.

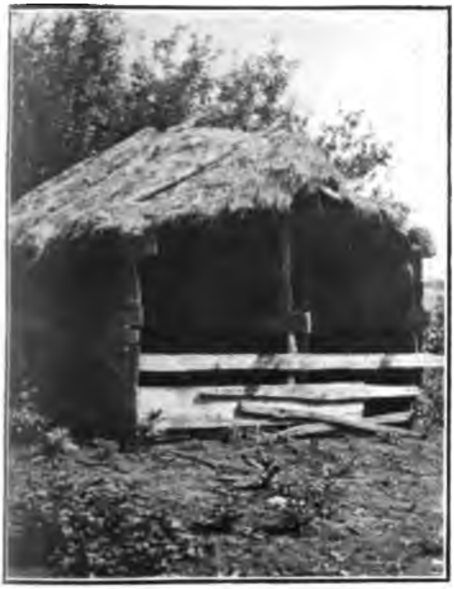

Fig. 1.—A Crudely Constructed Poultry House.

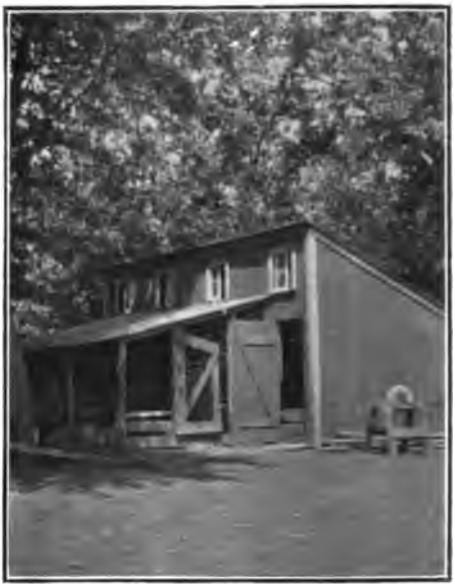

Fig. 2.—A Well-Constructed Poultry House.

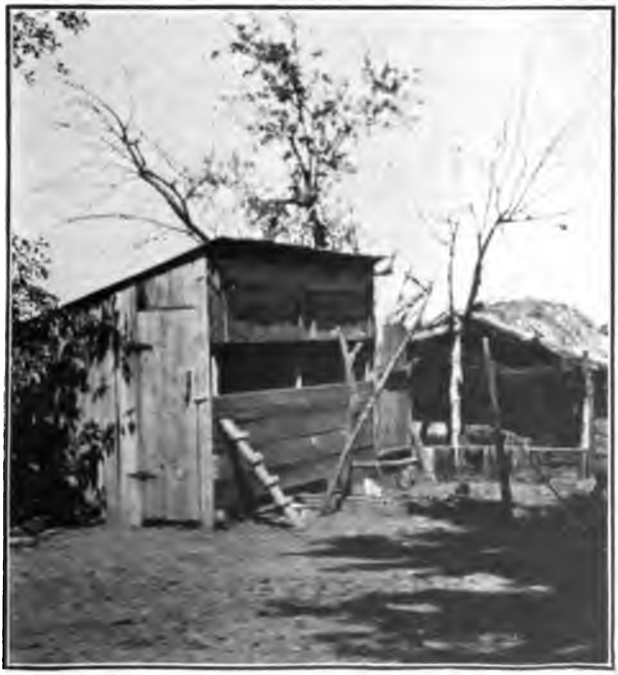

Fig. 3.—An Inexpensive Practical Farm Poultry House.

to be highly commended, since it prevents the accumulation of droppings on the floor, and also makes it easy to remove them.

No special attention was given to supplying the fowls with a liberal amount of fresh air, but because the majority of the houses are of crude construction, and also by means of small windows, doors, and numerous cracks and openings the fowls suffered little from the lack of ventilation. In relation to the amount of floor space per bird, it is a common occurrence to find from 75 to 100 fowls housed in a building of such dimensions that it allows each fowl only about 1 square foot of floor space, and it was easy to find cases where even less space than this was provided. However, where the fowls are allowed free range on all suitable days, and the house is cleaned at frequent intervals, the question of a definite amount of floor space per bird is not very important.

The farmer of the Middle West seldom, if ever, confines his poultry in yards, and there is no doubt that this has been a most important factor in maintaining the vigor and health of the fowls so admirably. The condition of the farm flocks in respect to these two qualities is well shown by the following figures from the 92 farms:

TABLE 5.—*Health and vigor of poultry flocks on 92 Kansas farms.*

Health.			Vigor.		
Good.	Fair.	Poor.	Good.	Fair.	Poor.
65	19	8	67	18	7

FEEDING METHODS.

During the spring, summer, and fall the fowls are compelled to forage for the greater part of their living. Even during the winter months they are fortunate if they receive more than one feed a day. Consequently they are compelled to pick up a considerable portion of their living around the barn and corncrib. This condition has arisen from the practice of giving the poultry free access to the feed lots for beef cattle and hogs. In feeding the steers and hogs the corn is often dumped in piles about the feed lot, thus making it possible for the fowls to procure a liberal feed of corn at least once a day. At thrashing time also there is considerable waste grain which would be a total loss if not utilized by the poultry. The fields of alfalfa make an ideal range and furnish abundant green feed. It is quite common to see the alfalfa stack in close proximity to the barn and other outbuildings, and in this case the fowls have green feed close at hand.

Where any attempt is made to supply the fowls with grain regularly once or twice a day the following feeds are generally used: Corn, wheat, kafir corn, and spelt. Of these the one most commonly used is corn. The fowls do not receive a regular supply of meat feed, and when insects are no longer available they are compelled to exist on an unbalanced ration of starchy grains. It is, however, a common practice to give the fowls the offal from whatever butchering may be done on the farm, and often the farmer may kill jack rabbits, which are sometimes used as meat feed for the poultry. The supply of meat feed is, however, very irregular. Practically every flock examined showed more or less feather pulling, thought to be the result of an insufficient supply of this material.

Crushed clam shells are used almost exclusively to furnish the fowls with carbonate of lime. Grit in the form of commercially prepared crushed stone is seldom used, but many farmers haul a load of coarse sand to the barnyard and allow the fowls free access to it at all times. Such a method is inexpensive to the farmer and furnishes the fowls with an abundant supply of grit.

The water supply for the poultry is usually both insufficient and insanitary. Vessels of every size and description, such as oven doors, milk-can tops, wooden troughs, pails, and cans of all sizes, are used as reservoirs for water. It is the exception rather than the rule to find these vessels clean and filled with water. They are more apt to be completely dry and dirty, while the fowls can be seen drinking from a cesspool in the barnyard or a wallow in the pigpen.

HATCHING AND BROODING.

There are two general systems of hatching and brooding the chicks: First, hatching and brooding with hens exclusively; second, hatching the eggs in an incubator and then giving the chicks to hens. The former is practiced to a greater extent than the latter, and in many instances a combination of both is used. Where this is done it is a general practice to set a number of hens at the same time, and when the hatch comes off the chicks are divided up among them. Many chicks are produced by hens stealing their nests, and this condition is responsible for a large per cent of the immature stock that is so noticeable in the fall and early winter.

If fowls are used exclusively for hatching and rearing, it is often difficult to get the chicks out early on account of the hens' indisposition to sit. It was largely to overcome this difficulty that the incubator has been adopted on the farm. A comparison of the relative frequency with which artificial and natural methods or a combination of the two are used, both in hatching and brooding, is given in Table 6.

TABLE 6.—*Methods of incubation and brooding used on 92 Kansas farms.*

Hatching.			Brooding.		
Natural.	Artificial.	Combination.	Natural.	Artificial.	Combination.
54	13	22	80	3	9

The methods of feeding the chicks are for the most part very simple. Some chicks are grown on nothing but corn meal and cracked corn, and others receive only millet seed until they are large enough to consume the coarser grains. There are many farms, however, where such extreme measures are not used, a happy medium being reached by using some commercial chick feed in connection with such products as are produced on the farm.

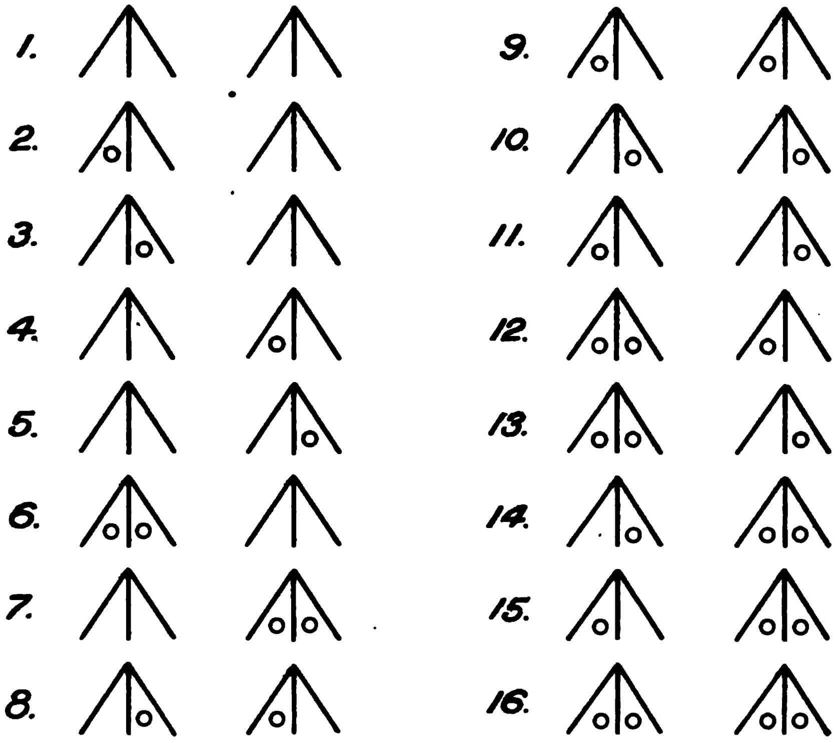

FIG. 1.—Method of toe-marking chicks to determine age. Sixteen different toe marks.

METHOD OF MARKING POULTRY TO DETERMINE AGE.

At the present time 95 per cent of the farmers have no positive method of determining the age of their poultry. From an economic standpoint it is very desirable that when a farmer markets a part of his stock he should be able by some accurate method to ascertain the age of the fowls which he sells. Such a plan would tend to decrease the enormous number of pullets and yearling hens which through lack of system are now being disposed of while old hens are often retained. Yearling hens and pullets especially will in the course of the year return to the farmer a greater profit from the eggs which they produce than will the older fowls. Hens can be kept at a good profit until they have passed their second year, but they are not as a rule profitable beyond that age.

The most common method of marking poultry is to leg-band them. These bands are manufactured from aluminum, wire, and composite metals, and are placed around the leg of the fowl and fastened in numerous ways. This system, while eminently satisfactory, requires more labor and attention than most farmers would care to give. A more practical method is by punching the web of the foot at the time the chick is hatched. The operation is simple and an entire hatch can be toe-marked in a short time. Figure 1 shows a diagram of a system by which 16 different combinations of toe-marking are possible. If only one mark is employed for all chicks hatched in a given year, no farmer would find it necessary to use more than three or four of these marks, but, if it were desired to show ages more closely, or to mark pedigree stock, all the forms indicated might be found useful.

INSUFFICIENT NUMBER OF NESTS.

While the conditions thus far discussed surrounding the keeping of poultry on Kansas farms have a great influence upon the number and size of the eggs produced and may also have some influence upon their quality, there are other conditions which have a much more direct influence upon quality and are responsible for the greater part of the deterioration which has occurred by the time the eggs reach the country store. Among these are, insufficient number of nests, dirty nests, irregularity in gathering eggs, allowing the males to run with the flock after the hatching season, poor storing facilities, washing eggs, holding for a definite number of eggs, and careless methods of transportation from the farm to the village.

It is doubtful if any other one factor contributes more to the aggregate number of bad eggs on the farm than the lack of a sufficient number of properly located, clean nests. The average number of nests on the Kansas farms observed is 11 to every 100 hens. This means that nearly 50 per cent of the fowls are compelled to seek nests for themselves. This condition is well shown in Table 7.

TABLE 7.—*Number of nests to number of hens kept on 92 Kansas farms.*

Nests to hens.	Number of farms.	Nests to hens.	Number of farms.
No nests	5	1 nest to 13 hens	4
1 nest to 100 hens	1	1 nest to 12 hens	6
1 nest to 57 hens	1	1 nest to 11 hens	3
1 nest to 50 hens	1	1 nest to 10 hens	12
1 nest to 37 hens	1	1 nest to 9 hens	3
1 nest to 33 hens	2	1 nest to 8 hens	6
1 nest to 30 hens	2	1 nest to 7 hens	5
1 nest to 21 hens	1	1 nest to 6 hens	5
1 nest to 20 hens	2	1 nest to 5 hens	7
1 nest to 18 hens	3	1 nest to 4 hens	5
1 nest to 17 hens	1	1 nest to 3 hens	3
1 nest to 16 hens	2	1 nest to 2 hens	6
1 nest to 15 hens	1	More than 1 nest to 1 hen	1
1 nest to 14 hens	3		

The horse stable, straw stack, under the corncrib, or out in the weeds are the places usually chosen by the hens when a sufficient number of nests is not available. It is well known that vigorous bacterial growth depends largely upon moisture and warmth, and these factors are usually present in such places. The result is that when a nest full of such eggs is discovered, from 50 to 80 per cent of them have already developed into seconds, blood rings, and rots.

The excuse is often given by farmers that if they went to the trouble and expense of providing liberal nesting facilities the hens would not utilize them, as they prefer the secluded nest of their own choosing. While it is true that in many instances hens will steal their nests rather than lay in places provided for them, especially during the spring which is the natural hatching season, it was observed that on the farms where nests were provided at the rate of one for every four or five hens, and were kept free from vermin, 95 per cent of the eggs were laid in these nests, and it was only occasionally that a hen would lay elsewhere.

DIRTY NESTS.

It hardly seems necessary to make any mention of dirty nests, but the investigations of the past year prove conclusively that either through carelessness, neglect, or utter indifference the nests often become so filthy that the hens refuse to lay in them. When such nests are used the new-laid eggs come in contact with the droppings of the fowls, which contain numerous bacteria, and the eggs may therefore become infected before they are removed from the nest. This does not necessarily mean that the eggs are unfit for food at this time; but the infection having taken place, they are likely subjects for the production of spots and rots. One of the greatest needs, therefore, in improving the condition of eggs on the farm is to provide an abundance of clean nests free from vermin.

IRREGULARITY IN GATHERING THE EGGS.

The practice of combining forces and organizing a general search party to gather in the eggs on market day is still practiced on many of the farms in Kansas. This is indeed a deplorable custom, and there is no question but that it is the cause of many rotten eggs. It is easy to see how eggs allowed to remain for several days or a week in the unsuitable places where they may have been laid, subjected probably to high temperature, wet by dew and by rain, and perhaps sat upon by a broody hen, are certain to have undergone serious deterioration if they are not absolutely spoiled.

MALES RUNNING WITH FLOCK AFTER HATCHING SEASON.

This is the usual rather than the unusual condition. Of the 92 farms, there were only 16 on which any effort had been made to separate the males from the hens after the hatching season, while on the remaining 76 farms the males and hens ranged together. Justification for this practice is sometimes sought in the argument that there will be some stolen nests that remain undiscovered for so long that even the conscience hardened by the case-count system of buying will not consent to their being marketed, and that if these eggs had been fertilized by allowing the males to run with the flock a part of the eggs would have hatched and the loss would not have been absolute. It should be borne in mind, however, that a much greater loss actually does occur when the eggs are fertile, for it is from the fertile eggs only that the great mass of bad and deteriorated eggs known as heated eggs, blood rings, and many of the rots develop. With the eradication of fertile eggs during the hot summer months, a large part of the problem of heated eggs would be solved. Surely this is not a difficult condition to bring about if each one would do his part.

INEFFICIENT STORING FACILITIES.

This is a serious difficulty with which the farmer's wife has to contend, as a great many of the country homes in Kansas do not have dry, cool cellars, and when the thermometer begins to register from 100 to 106° F., there is no good place to keep perishable produce. To overcome this difficulty use is often made of the "cyclone cellar," or cave. In some instances these caves are of concrete construction throughout, and on such farms very little difficulty is experienced in keeping eggs in good condition. Some of the caves, however, are nothing more than oblong holes in the ground over which a rough gable roof is built. The soil which has been excavated to make the cave is thrown over this roof and thoroughly packed so as to make it cool and practically waterproof. Caves of such construction are very hard to keep clean on account of the dampness and mold, which are always present when dirt walls and floor are used, and consequently they are very undesirable as a storage room for eggs. Dampness is conducive to the rapid development of mold and bacteria, and consequently eggs kept in these caves are much more likely to show deterioration than if they were held in a dry room at the same temperature.

WASHING EGGS.

The lack of the necessary number of clean nests and irregularity in gathering eggs, especially on rainy days, are the two main reasons why it is often necessary for the farmer's wife to wash part of the eggs. No one would ever accuse a neat housewife of taking dirty eggs to town, and in order to maintain this reputation they are very careful to see that each egg is clean before packing it in the case. This practice, while not always harmful, often results in the egg becoming contaminated with some form of micro-organism. The eggshell itself is porous and not germ proof, and the pores are large enough to allow the invasion of moisture and bacteria, but the membrane beneath the shell is comparatively germ proof so long as it remains dry; hence it is desirable that the eggs be clean in the first place, so that water will not have to be brought in contact with them.

HOLDING EGGS UNTIL A QUANTITY HAS ACCUMULATED.

The farmer often makes use of an egg case in which to keep his eggs and carry them to market. Sometimes he owns the case and sometimes it is furnished him by the storekeeper. Often the case is one holding 30 dozen eggs, and there is a tendency to wait until it is filled before taking it to market. As this would take considerable time with the average-sized flock, the quality of the eggs will have suffered appreciably. Smaller cases, holding 12 dozen eggs, are also used for this purpose and are much to be preferred, as they encourage more frequent marketing. Another factor which influences the frequency of marketing is the distance of the farm from the village or country store. The greater the distance the less often are the trips made and consequently the less convenient it is to market eggs frequently. Table 8 indicates this tendency.

TABLE 8.—*Distance from market in relation to frequency of marketing eggs on 90*[1] *Kansas farms.*

Twice weekly.		Weekly.		Once in two weeks.	
Number of farms.	Average distance to market.	Number of farms.	Average distance to market.	Number of farms.	Average distance to market.
	Miles.		*Miles.*		*Miles.*
26	2.48	61	4.12	3	8.5

---

[1] The two farms not included in this table did not send eggs to market during a large part of the year. In one case the eggs were used at home while in the other they were sold for hatching.

CARELESS METHODS OF TRANSPORTATION FROM FARM TO VILLAGE.

While this element of egg deterioration does not cause a marked loss or change in itself, because it occupies a relatively brief time, it is nevertheless a contributing factor. In figure 1 of Plate IV is shown a picture of the farmer and his family on their way to market. This particular drive was one of 8 miles and the egg case was exposed to the sun's rays during the entire trip. At the time the picture was taken the thermometer registered 106° F. on the top of the egg case.

THE FARMER'S MARKET.

The farmer may market his eggs through any one of the following agencies: (1) The country store; (2) the cash buyer; (3) the huckster; and (4) the cooperative creamery. Of these four outlets the country store is by far the most important. The reason why this system is so universal, together with the effect it has on the quality of the eggs, have already been discussed (see p. 14).

PRESENT FEATURES OF STORE DEALING.

Under the present system of buying loss-off, or on a quality basis, many of the storekeepers in Kansas have relinquished the handling of farm eggs. This is due in part to the fact that the merchant does not feel that he can go to the expense and trouble of candling, and also to the fact that if in defiance of the pure-food laws of the State he attempts to continue on the case-count basis, at the same time offering as much as his competitors who are buying on the loss-off basis, he is experiencing a much heavier loss on his eggs than formerly. If he does not offer as much as his competitors he is likely to get only the most undesirable class of eggs, which will increase his loss still more. What this loss may amount to in a single week will be seen from Table 9. The figures given were secured from one of the car-lot shippers and taken direct from the report of his candlers.

TABLE 9.—*Candler's report, showing losses in eggs received during one week in August, 1910.*

Shipper.	Total receipts.	Firsts.	Seconds.	Rots.	Loss from seconds at 6 cents per dozen.	Loss from rots at 15 cents per dozen.	Total loss.
	Dozen.	*Dozen.*	*Dozen.*	*Dozen.*			
Merchant A.......	180	106½	25	48½	$1.50	$7.28	$8.78
Merchant B.......	300	142	40	118	2.40	17.70	20.10
Merchant C.......	450	280	38	132	2.28	19.80	22.08
Total.......	930	528½	103	298½	6.18	44.78	50.96

In buying on the loss-off basis, the storekeeper would in all probability have made no distinction between the firsts and seconds, but

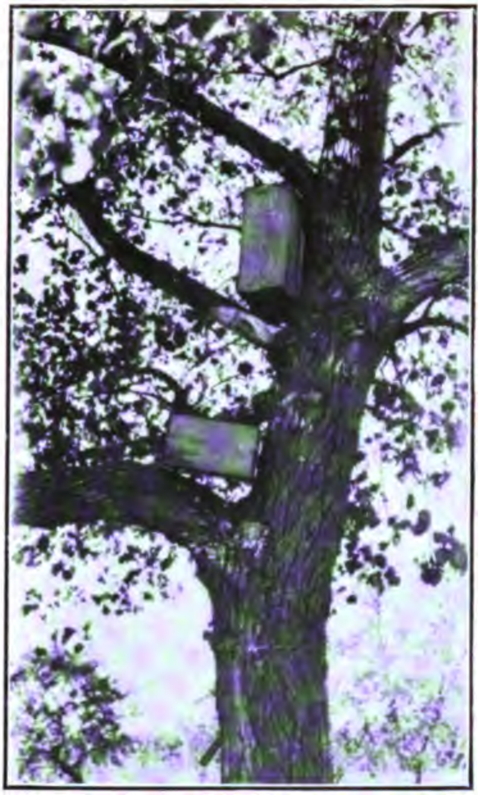

FIG. 1.—TREE NESTS, WHERE SOME KANSAS HENS LAY.

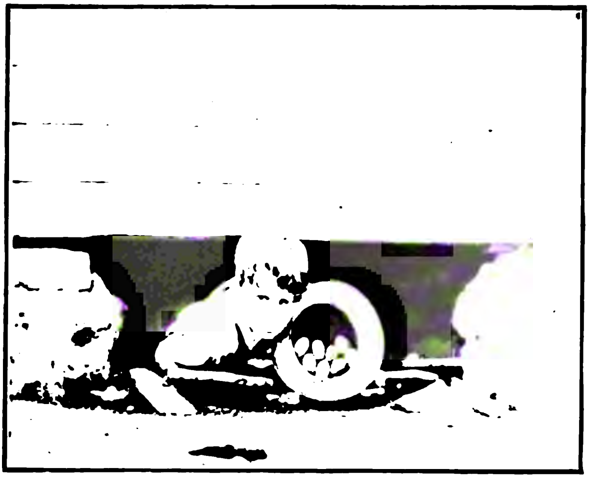

FIG. 2.—GATHERING EGGS FROM UNDER THE CORNCRIB.

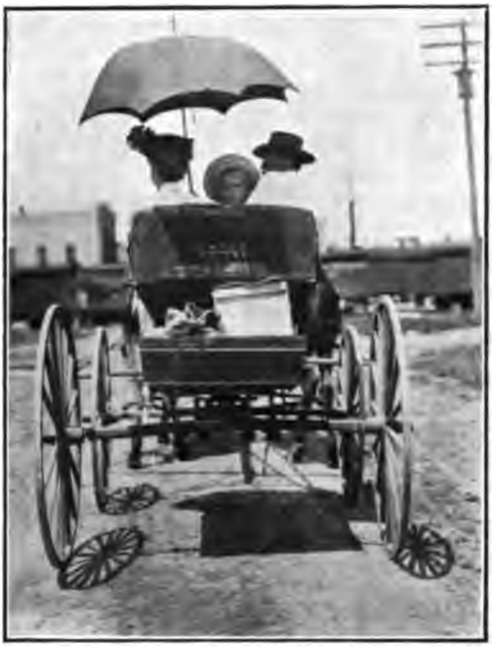

FIG. 1.—TAKING EGGS TO MARKET. EGG CASE EXPOSED TO SUN'S RAYS DURING 8-MILE DRIVE AT TEMPERATURE OF 106° F.

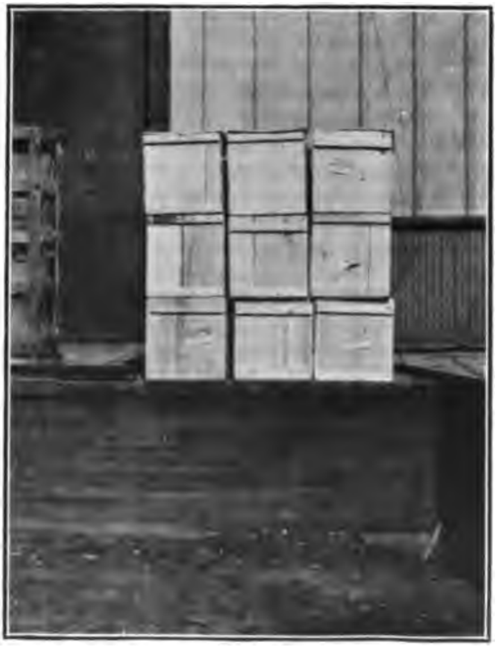

FIG. 2.—A SHIPMENT OF EGGS ON RAILROAD PLATFORM AWAITING ARRIVAL OF LOCAL FREIGHT.

[These cases stood in the sun for 6 hours in a temperature ranging from 110° to 130° F.]

would simply have thrown out the rots. The loss represented by the rots would, however, have been saved, excepting a small proportion which would have developed between the times the storekeeper and the candler handled the eggs.

Driving the local merchant out of the egg business is not inevitable, though in many respects it would be greatly to his advantage and to the advantage of the egg trade. Indeed, the merchants of some towns have voluntarily withdrawn by mutually agreeing to turn the egg trade over to the cash buyer, where it belongs. This is the simplest and best solution of the problem. It has also been suggested that the business be turned over to the produce dealer, who, instead of paying cash, shall issue scrip which will be taken at its face value in payment for goods at any of the local stores. The whole object of this plan is to compel the farmer to patronize home trade.

Other plans have been devised and are working with some degree of success which attempt to keep the benefits of the egg trade for the merchant, while at the same time relieving him of its unpleasant features. One of these allows the farmer to trade his eggs out on a case-count basis as before, but these eggs are kept separate. Each morning the receipts of the previous day are sold to the local cash buyer, who candles the eggs and reports the rots or bad eggs found in each individual lot. The merchant then charges the loss against the farmer's account and deducts it from the next lot of eggs brought in if he has no balance in his favor. By such a procedure the merchant is obeying the law, is helping to improve the quality of the eggs, is protecting himself against loss, and at the same time is retaining his egg trade. This means that instead of unloading inferior merchandise upon his customers, as he did when the case-count system was in vogue, he is able to give them full value for their money. He has no loss to figure and need not fear the competition of his fellow merchants or the large out of town mail-order houses. As soon as the farmer is made to realize that every merchant in town is going to candle his eggs, he immediately commences to take better care of them and carefully compares the prices on various articles of food and clothing as advertised by the merchants. Thus the whole problem simply resolves itself into the question of legitimate profits, and unless the merchant is selfish or money mad there is no logical reason why his prices can not be made as attractive as those of his competitors.

Aside from the method of buying, there are other conditions connected with the country store which should be remedied in order to give best results. The most prominent of these is infrequency in shipping. It is not uncommon for the storekeeper to allow his eggs to accumulate for a week or even longer before he ships them, and as he has no room specially equipped for holding eggs and must depend upon using the back part of his store or a cellar, this is a serious cause of deterioration. The produce dealer, on the other hand, understands better the necessity for moving the eggs as quickly as possible, and not infrequently ships daily during hot weather. Under such conditions little of the deterioration occurring can be laid at his door. In the country store it was frequently observed that the egg cases were piled alongside of merchandise of many kinds, among them barrels of kerosene, barrels and crates of vegetables, and other materials from which the eggs were almost certain to absorb undesirable flavors or odors.

THE CASH BUYER.

The cash buyer or produce dealer may be in business for himself or may be the agent of some large car-lot shipper or creamery company. His method of doing business is very similar to that of the country merchant, except that he offers cash instead of merchandise. He is often not looked upon with favor by the town merchants, because they realize that the farmer prefers the cash in order that he may purchase his merchandise from the firm offering the lowest prices. As long as the merchants were able to dispose of their eggs on a case-count basis they could, by offering 1 or 2 cents more per dozen in merchandise, retain the greater part of their trade. The enforcement of the loss-off system, however, is working a slow but sure change in this system and a greater proportion of the trade is going over to the cash buyer.

In studying the conditions found at the country store and at the cash buyer's the following card was used. This card is self-explanatory.

[UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF ANIMAL INDUSTRY.]

POULTRY AND EGG-MARKETING INVESTIGATIONS.

COUNTRY STORE OR PRODUCE DEALER'S CARD.

No. ----------
Name ----------
Address ----------
Date ----------
Sources of supply ----------
    Relative proportion from each source ----------
Frequency of receipts ----------
Character of payments ----------
Grading ----------
Methods of holding:
    Containers ----------
    Repacking ----------
    Nature of storeroom ----------
    Capacity of storeroom ----------
    Temperature of storeroom ----------
    Length of time held ----------
How shipped ----------
Size of shipment ----------

Frequency of shipping____

Distance from store to shipping point_____________________________

Length of railroad haul_______________________________________

Time consumed in haul____

Outlet ____

Name and address of person or firm to whom sold________________________

____

THE HUCKSTER.

The huckster or peddler who gathers eggs directly from the farm is rarely found in Kansas. This system is practiced in the States of Michigan, Indiana, Ohio, Kentucky, Tennessee, and the Northeastern States. Where the huckster operates in thickly settled localities and where it is possible to have a twice or thrice a week service, the eggs gathered by him constitute some of the best on the market, but where he makes a trip of a week or 10 days the eggs are exposed to many unfavorable conditions and are usually poor in quality.

THE COOPERATIVE CREAMERY.

The number of cooperative creameries handling eggs is not at the present time large. There are some places where this system is working successfully, and it is suggested as a feasible proposition in localities where conditions are favorable. The chief requisites necessary to operate such a system successfully are: (1) A well-established creamery whose manager is interested in the welfare and advancement of the community and who has by his straightforward dealings gained the confidence of the farmers. (2) A locality thickly enough settled to supply the creamery with sufficient eggs to maintain a trade in some near-by city. (3) A receptive and progressive body of farmers who will carry out their part of the agreement with the creamery. (4) A system of gathering up the cream and eggs by the creamery wagons or their delivery by the farmers at frequent and regular intervals. (5) A system of payment which shall, like the loss-off system, make each producer responsible for the quality of the eggs. (6) A market within easy shipping distance demanding good dependable eggs and willing to pay a premium for them. For a more detailed discussion of this subject the reader is referred to an article which appeared in the Twenty-sixth Annual Report of the Bureau of Animal Industry entitled "Marketing Eggs Through the Creamery," and reprinted as Farmers' Bulletin 445.

SHIPPING EGGS LOCALLY.

It is the general custom for the farmer in Kansas to dispose of his eggs through the country merchant or the cash buyer. The country merchant may in turn either sell to the local cash buyer or ship his receipts independently to commission men or car-lot shippers in surrounding cities. In most towns where cash buyers are located it is usual for the merchant to dispose of his receipts through this channel. In many towns, however, there is not enough business to support a cash buyer, and in such cases the merchants ship to the firm offering highest quotations. In cases where the cash buyer is a salaried agent of some large shipper or packer he of course forwards all receipts to the central plant, but should he be in business for himself the parties offering the best prices will receive the bulk of his trade.

In shipping the eggs both the country merchant and the cash buyer are often guilty of careless packing, which is responsible for a part of the breakage. It is a frequent occurrence to find old tattered fillers used which waste more money in time spent in packing the eggs in them than new ones would cost. Often no flats are used between the fillers, but a few thicknesses of newspaper are depended on to take their place. A small pad of excelsior should be placed in the bottom of each side of the case and on the top of the uppermost flats. These will provide elasticity and do much to prevent breakage. Frequently, too, the trouble is taken to nail the top of the case securely in the center. This is a mistake, as it prevents elasticity and is unnecessary if the top is nailed securely at the ends. Exceptionally large eggs, even though they may have strong shells, are almost sure to be broken if packed in the case, and will smear a large number of other eggs. In fact, any of the factors causing broken eggs result in a much greater loss than that of the eggs actually broken, for many others are so badly smeared that they must be classed in lower grades than they would otherwise be placed.

The eggs, after leaving the hands of the immediate collectors, are handled mainly by local freights. During this stage of their journey there is liberal room for improvement. The general rule of most railroads is that eggs or any other products which are to be shipped on the daily freight must be delivered at the depot at least one hour before scheduled train time. If all trains ran on scheduled time this rule would not be so harmful, but since this is the exception rather than the rule with the local freight, it often happens that the eggs remain exposed to the direct rays of the sun for several hours. During the months of June, July, August, and September the quality of the eggs suffers from this treatment. Plate IV, figure 2, shows a shipment of eggs which was exposed to the sun for six hours in a temperature ranging from 110° to 130° F. In accordance with the rule, these eggs were delivered at the depot one hour before train time. On this particular day, however, the freight was several hours late, and the eggs were allowed to remain in this extreme temperature until it arrived. Such a condition could be materially improved if the eggs were placed under a covered portion of the platform, where they would be protected from the sun. It is only fair to say that such covered shelters are often available, but they are seldom utilized.

When the cases are loaded on the train they are placed either in a box car or in one end of an open stock car which is also used for live poultry. (See fig. 2.) The box car often contains empty oil barrels and freight of similar nature. These box cars are opened when a stop is made, and then only long enough to load the shipments from that station. If the day is warm the temperature inside the cars will often go as high as 106° F. and remain at that point for hours.

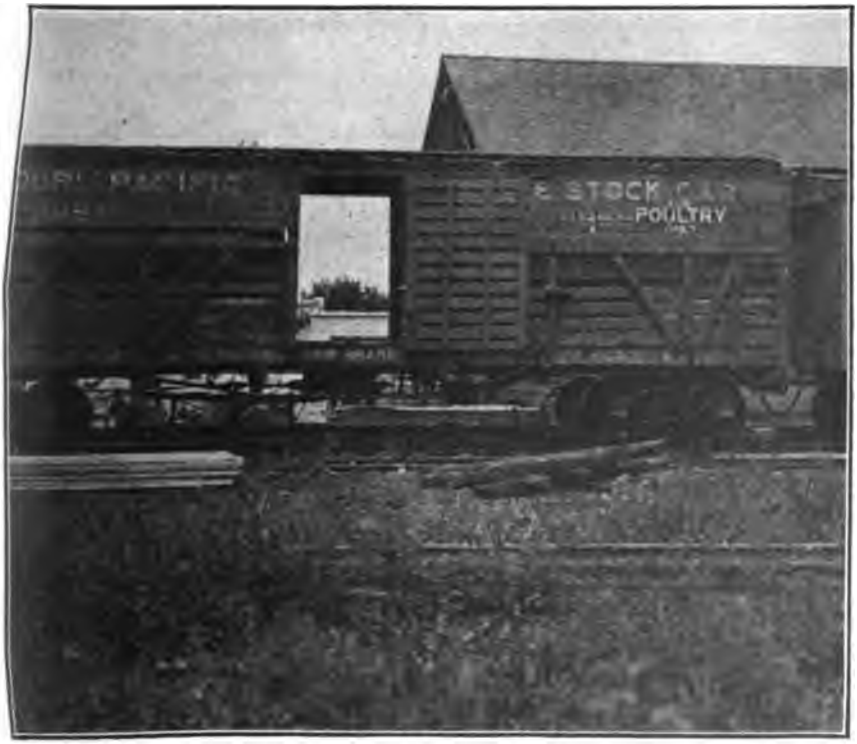

FIG. 2.—A stock car used for shipping poultry and eggs.

The temperature of the open stock cars is from 8 to 10 degrees lower than that in box cars during the hottest period of the day, and owing to the free circulation of air very much cooler after the sun has set. Coupled with this exposure to high temperature and injurious odors the eggs are, of course, subjected to violent but unavoidable shaking and jarring during the entire trip.

It should be said that at least one of the railroads operating in Kansas has taken a long step forward in the matter of handling eggs on the local freights. This road is running refrigerator cars into which the eggs are loaded, and the most favorable temperature possible to get under these conditions is maintained. Some of the packers consider this such an important feature in improving the quality of the eggs handled by them that they intend to run refrigerator cars at their expense over some of the lines from which they draw heavily.

The following are some of the most important ways in which the railroads can help in this movement for the improvement of quality in eggs: (1) Provide covered sections of station platforms and require that eggs waiting for shipment be stacked there out of the sun; (2) provide local refrigerator service for eggs; (3) if refrigerator service is deemed out of the question, provide stock cars rather than box cars for moving eggs during the summer months.

THE CAR-LOT SHIPPER.

After the eggs leave the hands of the country merchants and local cash buyers they are next handled by the packers and car-lot shippers. These men maintain central houses at important railroad junctions and at various other large towns and cities. They are keen, shrewd, business men, handling large quantities of eggs, so that they realize the necessity of good treatment after the product reaches their hands. While there is still room, no doubt, for considerable improvement in methods from this point on, this end of the trade is much further advanced at the present time than that represented by the producer and storekeeper, so that the greatest need for the improvement of methods of handling and thus of improving the quality of eggs is from the farm to the packing house.

During the course of the investigation of conditions it was found desirable to carry on certain experimental work. This consisted of following shipments of eggs which had been subjected to various conditions through to the packing house to determine the changes which took place. In this work a card, the front and back of which is shown below, was used in assembling the data. The work along this line thus far conducted is not yet sufficient to be conclusive, and is not, therefore, discussed in this bulletin.

[Front of card.]

[UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF ANIMAL INDUSTRY.]

POULTRY AND EGG-MARKETING INVESTIGATIONS.

HANDLING EGGS.

Observer .... Date .... Experiment No. ....
Statement of experiment ....
....
Material used ....
....
Eggs produced by .... Farmers' Card No. ....
Date laid .... Where held ....
Container and its condition .... How long held ....
Date and hour left farm for market ....

Haul to market or store by farmer: Time .... Miles ....
Container ....
Wagon .... Condition of road ....
Haul to market or store by egg collector or huckster: Card No. .... Time .... Miles ....
Container ....
Wagon .... Condition of road ....
Store or buyer to whom sold .... Card No. ....
Date received at store .... How long held ....
Where held .... Container and its condition ....
How packed for shipment .... Kind and condition of cases and fillers ....
Date and hour left store for station .... Length of haul ....
Where held at station .... How long held .... Covered or uncovered ....
Size of shipment .... Time put on car ....
Kind of car .... Eggs alone or eggs and poultry in car ....
Length and time of railroad haul .... Reloaded ....

[Back of card.]

Date and time of arrival at packing house ....
How handled at packing house: How long before put in cooler .... Temperature of cooler ....
Candling before or after cooling .... Grading .... Packing ....
Time held .... How shipped ....
Date and hour put in car for shipment .... Kind of car .... Time of shipment ....
To whom shipped .... Date of shipment ....
Remarks: ....

GRADE OF EGGS.

	Total eggs.	Full and fresh.	Badly shrunken.	Spots.	Blood rings.	Rots.	Checks.	Leakers.
At farm just before marketing								
At store on arrival								
At store just before shipment								
On arrival at packing house								
On leaving packing house								

EDUCATIONAL WORK.

It must be remembered that while the farmers and storekeepers have a general idea of some things which cause eggs to spoil, there are many others of which they are unaware, and the importance of few, if any, are fully realized. In all probability they have not given the matter much thought, and since they have been able to sell all the eggs they produce, though at a comparatively low price to be sure, they have not realized that they are actually losers as the result of the spoiled eggs. It is necessary, therefore, to educate the farmer especially to the true condition of affairs.

In its work the bureau has kept this point in mind and has made an effort to disseminate information on the matter wherever possible.

The packers and car-lot shippers have also realized the benefits which would accrue from giving the matter publicity and have distributed circulars and other printed matter pointing out the most essential features to be observed in caring for eggs.

In connection with the investigation of conditions on the farm the men engaged in this work came into personal contact with a large number of farmers and housewives and explained to them the aims of the movement and the benefits to be derived from it. It is interesting to note that in the case of nearly all farmers visited greater interest is now being taken in their poultry, and much greater care is being given to the eggs. It is a noticeable fact that as soon as a farmer becomes interested in better poultry or in better methods of caring for them he takes better care of the product. Special pains were taken, therefore, to give good practical help along any poultry lines which the farmer wished. The desire for information concerning housing, feeding, etc., also the best breeds to keep, and as to which were the best birds in the flock, etc., was astonishing. By supplying this information the confidence of the farmer was won and his help and support secured in the effort to improve the quality of the eggs.

Many country stores were also visited. The object of these visits was to become acquainted with the merchants and discuss with them the loss-off system of buying. The majority of these merchants know little or nothing about candling, and by practical demonstration it was possible to show them that it would not be a very difficult matter to become expert enough to be able to detect rots, spots, and blood rings.

Some educational work can also be carried on through the poultry shows. Anything which increases the interest in better poultry helps along the movement for the improvement of eggs. Poultry shows, particularly those held in the smaller towns, have a great influence along this line. A judge who will spend some time explaining the good points of birds and giving reasons for awards can increase the educative value of the show wonderfully. Exhibits of eggs and market poultry can often be arranged. Packers or produce men can occasionally be found who will provide attractive prizes for these classes. The bureau has in some instances furnished judges for these small shows and has frequently sent speakers for the purpose of giving talks concerning the care and handling of eggs. It has also been possible to extend the educational work by referring those interested to the publications of the United States Department of Agriculture and those issued by the State experiment stations on poultry subjects.

RESULTS OF FIRST SEASON'S WORK.

Although but one season has been spent by the bureau in this work, several much-desired changes have been brought about. The most important of these was the adoption by the Kansas car-lot shippers of the loss-off system of buying and selling eggs. The immediate effect of this system was a marked improvement in the quality of Kansas eggs, and this was so apparent to the men engaged in handling them that they became intensely interested in the bureau's work and voluntarily offered their assistance in every possible way.

EXTENSION OF THE MOVEMENT TO OTHER STATES.

As a result of its success during the past summer, the loss-off system of buying has become more firmly established in Kansas. It also led to a meeting at Kansas City, on December 20, 1910, of the State pure-food officials from Kansas, Nebraska, Iowa, Missouri, and Oklahoma, with a committee of car-lot shippers of eggs, to discuss the matter of administration and the enactment of suitable legislation. It is believed that the Kansas law may be improved upon so that the work may be made more effective, and for the purpose of enacting uniform legislation in the States represented the following bill was drafted at the meeting for recommendation to the respective legislatures of the States represented:

AN ACT For the protection of public health and the prevention of fraud by regulating the sale of eggs for food purposes, providing penalties for the violation thereof, and providing for the enforcement thereof.

Be it enacted by the Legislature of the State of Kansas:

SECTION 1. It shall be unlawful for any person, firm, or corporation engaged in the buying and shipping of eggs, to buy, sell, barter, trade, or deliver, or to offer to buy, sell, barter, trade, or deliver any eggs for food purposes between the 1st day of June and the 31st day of December of each year, without first candling said eggs, or causing the same to be candled; and any such person, firm, or corporation who shall buy, sell, barter, trade, or deliver, or offer to buy, sell, barter, trade, or deliver any such eggs without first candling the same, or causing the same to be candled, and without first removing all decayed, decomposed, and spot eggs from those candled, shall be guilty of a misdemeanor and punished as hereinafter provided.

SEC. 2. The word "candle," as used herein, shall be construed to mean the examination of eggs by means of natural or artificial light, in such a manner as to disclose to the person examining the same whether the eggs so examined are decayed, decomposed, or spot eggs.

SEC. 3. That the State board of health is authorized and directed to make and publish uniform rules and regulations, not in conflict with the laws of this State, for carrying out the provisions of this act. Any person who shall violate any of the rules and regulations so made, and published in the official State paper, shall be deemed guilty of a misdemeanor, and on conviction shall be punished by a fine of not less than ——— dollars, or more than ——— dollars.

SEC. 4. That a case of eggs shall contain 30 dozen, and it shall not be considered as a violation of this act for any person, firm, or corporation to buy or sell, or offer to buy or sell, any case of eggs for food purposes that does not contain more than 2½ per cent of decayed, decomposed, or spot eggs.

SEC. 5. Any person, firm, or corporation convicted of violating any provision of this act shall be punished by a fine in the sum of not less than ——— dollars, nor more than ——— dollars.

SEC. 6. This act shall take effect and be in force from and after its publication in the statute book.

In addition to the States named, there is considerable interest on the subject manifested in other Western States. The senior author of this bulletin was invited to meet the State dairy and food commissioner and egg buyers of South Dakota in January for the purpose of discussing methods of improving the egg trade in that State, and also addressed the Michigan Car Lot Shippers' Association at their annual meeting in Detroit in February, 1911, where much interest was evidenced in the subject.

In inaugurating such a movement, the first essential is an organization of buyers agreed to buy only on a loss-off basis; the second is the firm cooperation of the State authorities to prevent the shipment of bad eggs within the State. The one is practically useless without the other.

SUMMARY.

The Bureau of Animal Industry carried on work during the summer of 1910 in the State of Kansas with the object of improving the quality of the eggs marketed in that State. As a result of this work, the loss-off method of buying eggs has been quite generally adopted by the car-lot shippers and has resulted in a most gratifying improvement in the eggs. Considerable interest in the movement has been aroused in other States, so that it bids fair to spread rapidly.

In connection with the work a careful investigation of all the conditions surrounding the handling of eggs, from the time they are produced on the farm until they reach the packing house, has been made for the purpose of determining the preventable factors causing loss of quality. As a result of this investigation the following suggestions are made for the farmer. the country merchant and cash buyer, the railroad, and the car-lot shipper.

SUGGESTIONS FOR FARMER.

1. Improve your poultry stock.
2. Keep one of the general-purpose breeds, such as the Plymouth Rock, Wyandotte, Orpington, or Rhode Island Red.
3. Provide one clean, dry, vermin-free nest for every four or five hens.
4. Conclude all hatching by May 15 and sell or confine male birds during the remainder of the summer.
5. Gather eggs once daily during ordinary times, and twice daily during hot or rainy weather.

6. In summer place eggs as soon as gathered in a cool, dry room.
7. Use all small and dirty eggs at home.
8. Market eggs frequently—twice a week, if possible—during the summer.
9. In taking eggs to market protect them from the sun's rays.
10. In selling, insist that the transaction be on a loss-off basis, for if care has been given the eggs this system will yield more money to the producer.

SUGGESTIONS FOR THE COUNTRY MERCHANT AND CASH BUYER.

1. Candle all eggs and buy on a loss-off basis.
2. Allow the farmer to see you candle his eggs occasionally and return those rejected if he wishes them.
3. Pack carefully in strong clean cases and fillers.
4. Do not keep in a musty cellar or near oil barrels or other odoriferous merchandise.
5. Ship daily during warm weather.

SUGGESTIONS FOR RAILROAD OFFICIALS.

1. Provide a covered portion of station platforms where egg cases can be stacked and see that the agent stacks them there.
2. Provide refrigeration for the eggs on the local freight.
3. Where refrigerator cars are used on local freights, see that the doors are kept closed when not loading.
4. If refrigeration can not be supplied, provide stock cars rather than box cars for this purpose during the summer.
5. Where box cars are used for eggs do not allow freight which may hurt their quality, such as oil barrels, to be loaded in the same car.

SUGGESTIONS FOR THE CAR-LOT SHIPPER.

1. Buy strictly on a loss-off basis.
2. Encourage the smaller buyers to trade on a loss-off basis.
3. Join the State Car Lot Shippers' Association.
4. Cooperate with other shippers and the State officials in bringing about this system of buying.
5. Keep the subject agitated and before the people. In other words, educate them.

O

Issued August 3, 1911.

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BUREAU OF ANIMAL INDUSTRY.—BULLETIN 142.
A. D. MELVIN, CHIEF OF BUREAU.

DOURINE OF HORSES:

ITS CAUSE AND SUPPRESSION.

BY

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Chief of the Pathological Division

WASHINGTON:
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1911.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., July 5, 1911.

Sir: I have the honor to transmit herewith and to recommend for publication as a bulletin of this bureau a manuscript entitled "Dourine of Horses: Its Cause and Suppression," by Dr. John R. Mohler, Chief of the Pathological Division.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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DOURINE OF HORSES: ITS CAUSE AND SUPPRESSION.

INTRODUCTION.

On May 27, 1911, the Bureau of Animal Industry received a letter from Dr. J. I. Gibson, State veterinarian of Iowa, stating that there was in Taylor County an outbreak of a disease suspected of being dourine, and requesting that an expert be sent to make an investigation. The disease had been reported by Dr. A. H. Quin, a practitioner of Creston, Iowa, and his diagnosis was subsequently confirmed on the part of the bureau by Drs. A. D. Melvin, E. T. Davison, and the writer, who were of the unanimous opinion that the symptoms and lesions manifested were the most typical of any of the cases they had observed. Three of the affected mares were at once purchased and sent to Washington for experimental purposes. After a careful and prolonged examination of almost 200 slides, six living, wriggling trypanosomes, *Trypanosoma equiperdum,* were found on June 28, 1911, by the writer in the blood-tinged serum obtained from a recently developed plaque on the abdomen of one of the mares (No. 79), thus confirming the diagnosis and also establishing the identity of the disease with that of Asia, Africa, and Continental Europe. This is the first discovery of the *Trypanosoma equiperdum* in the natural cases of dourine in the United States, although in 1903 considerable work was done with this trypanosome imported from France and subsequently inoculated into horses at the Bethesda Experiment Station. Previous to 1911 there had been no authentic case of dourine reported among the horses of this country since 1906, although there had been a number of alleged or suspected cases brought to the bureau's attention from time to time which demanded a full investigation, but always with negative results. The object of this paper is therefore not only to describe the methods which have been employed in suppressing this insidious disease of horses but also to furnish such a description of the symptoms and lesions as to make it easier to differentiate dourine from other diseases which may simulate it. The chronicity of the affection, its ultimate fatal results, and the valuable breeding animals which are usually attacked, make it of considerable economic significance and render its early recognition and the subsequent enforcement of prophylactic measures extremely important to the horse breeder and the sanitarian.

NOMENCLATURE.

This disease has been described under various names, according to the country in which it is found, chief among which may be mentioned "el dourine," "maladie du coït," covering disease, equine syphilis, genital glanders, breeding paralysis, chancrous epizootic, epizootic paraplegia, and "beschälkrankheit." The most commonly employed name for this affection in the United States is the short and distinctive term "dourine," which is taken from the Arabic, meaning "unclean."

HISTORY.

The primeval home of the malady is supposed to be in Asia, where it is considered to have existed for centuries. It was first definitely described in 1796 by Ammon as occurring among the animals belong- to the sovereign of Prussia at Trakehnen. During the first half of the nineteenth century it was described as occurring in many countries of Europe, including Germany, France, Austria, and Switzerland. It was also known to be prevalent along the northern region of Africa in Algiers. It is supposed to have been introduced during the early part of the nineteenth century into Continental Europe through the importation of breeding horses, especially Arab stallions, from the Orient.

In the United States the disease was first suspected in 1885 and recognized in 1886 by Dr. W. L. Williams, who was then a practitioner at Bloomington, Ill. The infection was traced to a Percheron stallion, imported from France in 1882, which had a brand mark under the mane very much resembling the letter D (dourine?). It is supposed that he was affected with the disease and had been branded in France before being transported to this country. The nature of the disease not being at first recognized, its dissemination occurred before attention was attracted to it. The State of Illinois, however, took hold of the outbreak and as a result of rigid prophylactic measures the disease was eradicated from the State in 1888, but not before an affected stallion had been shipped to Gordon, Nebr., thereby starting up a new center of infection in that locality.

In 1892 dourine was again brought into public notice by the appearance of an outbreak among the breeding horses of northwestern Nebraska, the history of which suggested that it originated with this Gordon stallion. An inspector of the Bureau of Animal Industry investigated the outbreak and found that upward of 200 mares and stallions were affected with the disease. Steps for the eradication of this outbreak were begun in June, 1893, at which time some of the diseased animals had died, and the breeders were using all the precautions possible to prevent its spread. Under the authority of the Secretary of Agriculture all diseased animals still alive, including 32 in Nebraska and 5 in South Dakota, were purchased and destroyed.

After an expenditure of about $5,500 the disease was considered to have been eradicated from that section of the country. Five years later the infection again made its appearance in the same portion of Nebraska, and early in 1899 the bureau again began the work of eradication. Many inspections were made and those animals which were found diseased were purchased and killed. Many obstacles were encountered and the disease evidently kept smoldering during 1900.

In 1901 the infection appeared with increased vigor, this time in the Pine Ridge and Rosebud Indian Reservations in South Dakota, in addition to northern Nebraska, and more stringent measures were immediately inaugurated to control the spread of the disease. During the next year 10 diseased stallions and 76 diseased mares were purchased and slaughtered and 29 diseased stallions were castrated. However, eradication in this region was extremely difficult, owing to the wild condition of the country as well as of the horses and from the fact that many horse owners would try to conceal from the inspectors animals which they knew to be affected with the disease. This reappearance of the disease among horses in Nebraska and South Dakota after it apparently had been stamped out caused a thorough investigation of its latent qualities and other peculiarities, and as a result Veterinary Inspectors E. T. Davison and W. J. Fretz were stationed at Rushville, Nebr., with instructions to prosecute vigorously the work of eradication. In 1903 there were 16,287 horses inspected, of which 511 were found diseased and were killed, while 1,899 stallions were castrated. Careful and vigorous work was continued in this way, with the result that 8,705 horses were inspected in 1905, but only 1 stallion and 8 mares were found suspicious and destroyed and 9 stallions castrated.

During the year 1903 dourine was reported in Van Buren County, Iowa, and steps were immediately taken to stamp it out. As a result 410 horses were inspected, 2 exposed stallions were castrated, and 18 mares slaughtered. No connection could be established between this outbreak and that in Nebraska, but it was quite definitely determined that an imported Percheron stallion purchased by a company of farmers was responsible for its appearance.

In 1906 the last suspicious cases of dourine—1 stallion and 2 mares—were destroyed in South Dakota, and sufficient time has since elapsed to warrant confidence that the disease has been completely eradicated from that section of the United States.

In Canada the presence of dourine was discovered by Dr. Burnett in 1904, and the causative trypanosome was demonstrated by Dr. Watson in 1907, from the vulva of a mare. From the occurrence of this disease until the latest available published report in 1909, 628 animals were purchased and destroyed. A marked diminution in the number of infected animals is apparent in the report, and the disease is said to be under control.

As already stated, an outbreak of dourine has recently (June, 1911) been located in Taylor County, Iowa, where 4 stallions have been found affected and 5 exposed to this disease. One of the former stallions has since died of the infection. In addition, 5 mares have shown symptoms of dourine, 1 of which subsequently died of the disease, 9 are suspicious cases, and 94 have been exposed, but at present show no evidence of infection. These diseased animals, together with all exposed stallions and mares, were immediately quarantined by the State. Those showing lesions of the disease were purchased by the Government and destroyed, while the exposed animals are still in quarantine under observation. Several Federal and State inspectors are making farm-to-farm inspections with the view of discovering any latent or hidden cases, and it is now believed that the infection is entirely under control. The source from which this center of infection was derived is only a matter of conjecture, but there is apparently no connection between this and any of the previous outbreaks. No authentic information as to the origin of the outbreak has been discovered up to the present time, but all cases lead back to a Percheron stallion, which was imported in 1909 and brought direct to Lenox, Iowa. The possibility of such animals bringing the infection into this country must be apparent from the following explanation.

Schneider and Buffard maintain that in France dourine appears nearly every year in the Department of Basses-Pyrenees on the Spanish frontier. It is stated that mares get infected by the asses or horses by which they are covered. It is the custom to have a mare first covered by an ass, and if not impregnated she is then served by a stallion. The asses operate on both sides of the frontier, and in this way introduce the disease into France from Spain, where it has been known to occur for years, especially in Navarre.

DEFINITION.

Dourine is a specific infectious disease affecting under natural conditions only the horse and the ass, transmitted from animal to animal by the act of copulation, and due to a single-celled animal parasite or protozoan, the *Trypanosoma equiperdum.* It is characterized by an irregular incubation period, the confinement of the first symptoms to the genital tract, the chronic course which it runs, and by finally producing complete paralysis of the posterior extremities, with a fatal termination in from six months to two years.

CAUSE.

Many widely different theories as to the exact cause of this affection have existed and been advocated in the past 50 years. The fact that the disease spread from animal to animal in certain centers of infection, and that large horse-breeding districts and countries which did not import any breeding animals, such as New Zealand, Australia, England, and South America, remained free from the disease, showed it to be of an infectious nature. Investigations by Thanhoffer resulted in his obtaining bacilli, cocci, and streptococci from the blood and nervous system of animals dead of this disease. However, none of these organisms were invariably present, and from the fact that the disease was confined almost exclusively to breeding animals and seemed to be transmitted solely through the act of copulation doubt arose as to the likelihood of any vegetabie organisms being the causal agent in its production and dissemination. At one time it was considered to be identical with human syphilis and was thought to be conveyed from man to asses and mares, but the fallacy of this belief was demonstrated by Haussman and Knauert.

As opposed to the theory of coition playing the entire part as a means of transmission of the disease, we have the statements of Hayne and Haxthusen, who have reported the disease in geldings and also in mares which have never had sexual intercourse with the stallion. It may be also transmitted with ease artificially by means of inoculation into horses, dogs, rabbits, rats, and other susceptible animals, with relatively large quantities of the blood and membranes of certain organs of animals affected with the disease. However, sexual intercourse is by far the most common means of transmission, and if other means do exist they are so rare that they have little or no practical importance in the adoption of measures for the suppression of the disease.

It was not until 1896 that the true cause of the malady was discovered by Rouget, but his work was neither credited nor confirmed until 1899. At this time two French army officers, Schneider and Buffard, proved that trypanosomes were associated in causal relation to the disease, by successful inoculations of animals with organisms from an infected stallion. Later Nocard verified these results, and subsequently, in 1901, Laveran and Mesnil carefully described the trypanosome, naming it *Trypanosoma rougeti* after its discoverer, although it had previously been named by Doflein, *Trypanosoma equiperdum*.

TRYPANOSOMA EQUIPERDUM.

This trypanosome is a unicellular animal parasite (flagellate) very closely resembling the numerous other varieties of trypanosomes which have during the last few years been proved to be the causes of several tropical diseases of animals, chief of which may be mentioned surra, nagana, and mal de caderas. When taken from the blood of an infected animal it is a somewhat spindle-shaped organism with the posterior extremity bluntly conical; anteriorly (the head) it is prolonged into a long, wavy, whiplike flagellum, giving the appearance of a tail, thus apparently reversing the true position of the tail and head. (See Pl. I, fig. 1.) Along one side is a wavy, undulating, flangelike membrane terminating in the flagellum. The nucleus is large and located centrally, while the centrosome or kinetonucleus is situated posteriorly, and is the starting point of the undulating membrane and flagellum. The trypanosome is actively motile, but not so much so as certain other forms found in rats. Motion may occur indiscriminately forward or backward by the rapid lashing movements started in the flagellum and continued in the vibratory movements of the undulating membrane; also by the contraction of the protoplasm of the body. The size varies from 25 to 30 microns in length by about 2 microns thick.

The most satisfactory way of determining the presence of these parasites is to examine fresh preparations of the suspected fluid spread in a thin layer on a slide, covered with a cover slip and viewed with a 4-millimeter objective and No. 4 ocular. The trypanosomes may be readily stained and their structure brought out well by Giemsa's azur-eosin stain, Nocht's modification of Romanowsky's method, or by Borrel's blue.

In order to make a complete study of this protozoan as it exists in France and Algiers, a small dog was imported by the writer for the bureau in 1903 after being inoculated in Prof. Nocard's laboratory at the Alfort Veterinary School with blood infected with *Trypanosoma equiperdum.* This animal arrived safely in this country in an apparently healthy condition, giving rise to apprehensions as to the success of the inoculation. In a few weeks, however, it began to show signs of illness. The temperature rose to 103° F.; the sheath and the inside of the thigh became swollen and edematous. These swellings at first would disappear for a day or two, only to recur over a larger area. The animal became considerably emaciated, the edematous swellings spread, involving the whole inner surface of the thighs, as well as the entire length of the sheath, the appetite became poor, and the animal died in November, about 6 weeks after its arrival or 8 weeks after the inoculation. During the life of the dog after the first appearance of symptoms microscopic examinations were made daily of the blood taken from the peripheral circulation as well as from the serum in the edematous areas about the genitals for the purpose of recording the trypanosomes present, but they were always extremely scarce. After death these organisms were found in great numbers in the heart, blood, lungs, liver, kidneys, and spleen.

It was with the trypanosomes obtained from this dog, kept alive by continued passage through white rats, rabbits, dogs, and horses, that most of our work with the organism has been done. White rats were by far the most satisfactory experiment animals for the

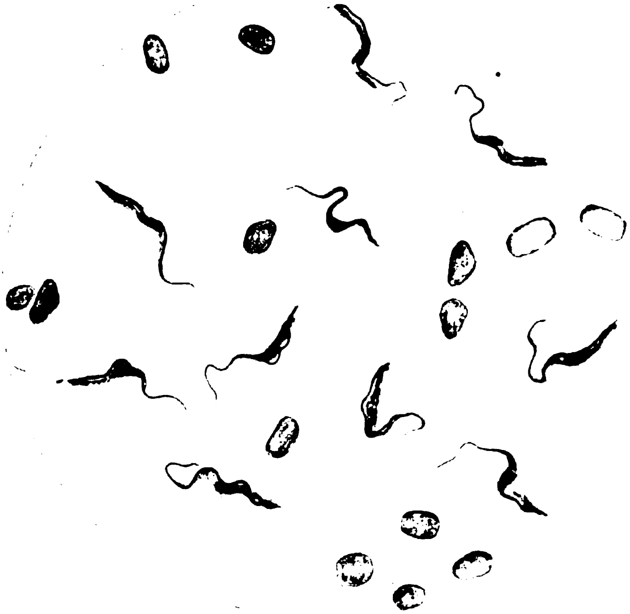
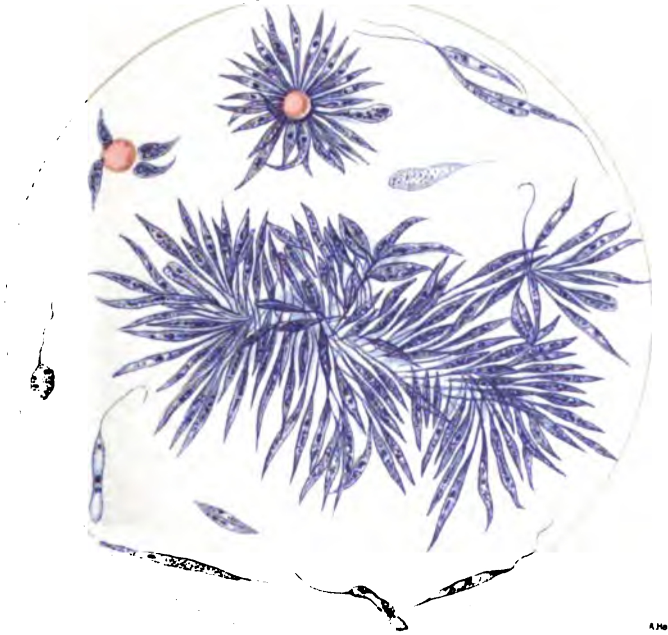


FIG. 1.—TRYPANOSOMA EQUIPERDUM FROM PLAQUE ON MARE 79. (COMPOSITE DRAWING.)



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A.Hoen & Co. Baltimore

FIG. 2.—TRYPANOSOMA EQUIPERDUM FROM A CULTURE.

propagation of the organism, as it proved much more pathogenic for them, death usually occurring in from 2 to 6 months after inoculation. The trypanosomes were also more readily recovered from these animals. Although rabbits after inoculation became gradually emaciated and finally died in from 2 to 8 months, it was only by long and careful microscopic examination that any trypanosomes could be found in their viscera after death.

The length of time which this protozoan lives when kept in blood or body fluids taken from the dead animals varies considerably, but is generally stated as being a very short time. Thus Rouget observed it to keep its motility for 18 hours, but never after 24 hours. In the blood of the French dog, as well as in physiologic salt solution emulsions of the liver and spleen, the parasites were actively motile on the second day, a few were still observed on the third day, but on the fourth day none could be found, showing that all were destroved between 72 and 96 hours after the death of the host.

CULTIVATION OF THE TRYPANOSOME.

The attempts at cultivation of this organism were attended with a great many difficulties, as it was rarely possible to obtain the organisms in sufficient concentration to get more than a few trypanosomes in each tube of media. Contaminations were also frequent, as hanging drop preparations made under perfectly sterile precautions from the blood and organs of the rats showed bacteria in numerous cases within one-half hour after death. The media also had to be made up fresh continually, as the water of condensation dried out and the color of the blood in the media rapidly became dark, due to the breaking up of the hemoglobin, after which change the material was of little value for the growth of the parasite. The medium used in these experiments was blood agar prepared after the method suggested and used by Novy and McNeal.

Rabbits' blood was used throughout the experiments. The blood was drawn from the carotid artery through a sterilized glass tube into sterile potato tubes containing sterile beaters with which the blood was defibrinated. More satisfactory results were afterwards obtained with less danger of contamination by securing all the blood in one flask. The sterile defibrinated blood was then mixed with equal parts of melted neutral or faintly alkaline agar, or in the proportions of 2 parts of blood—or, better, 3 parts—to 1 of agar, and allowed to solidify in the slanting position, after which the condensation water was inoculated. Great care had to be taken in keeping the constituents of the medium sterile during all the manipulations, as the sterilization of the finished product was impracticable, owing to the firm coagulation and alteration of the blood by the heat.

Rouget attempted to cultivate the *Trypanosoma equiperdum* at 37° C., but was uniformly unsuccessful, the organism never multiplying and only remaining alive for 24 hours. The same results attended all our early efforts, although the cultures were invariably kept at room temperature. The organism, however, seemed to flourish in white rats, and, if anything, it became more virulent for them by successive inoculations, appearing in greater and greater numbers in the blood and viscera at post-mortem until finally hanging-drop preparations made from the blood seemed to be alive with the minute wriggling organisms. One loopful of this blood would contain probably 200 or even more of these trypanosomes. The continued inoculation of a medium composed of three parts of blood to one of agar with such great numbers of the organism was finally crowned with success, since which time 14 generations have been grown, covering a period of over nine months, and no difficulty was experienced in keeping the trypanosomes alive by frequently transferring them to fresh medium. The cultures were finally destroyed through contamination of the media. The inoculation of experiment animals with these cultures seems to indicate that there was some reduction in their virulence, but too small a number of inoculations have been made to draw definite conclusions.

The first three attempts at cultivating this protozoan were direct failures, as the 6 tubes used in the first two cases and 9 in the third failed to show any trypanosomes after the fourth day. The fourth inoculation, consisting of 11 tubes made on March 9 with blood agar (3 to 1) resulted in the multiplication and development in one tube of trypanosomes, but after the sixteenth day this encouraging culture died, and despite subinoculations no further growth could be obtained. On April 12 a fifth attempt was entirely successful, as 3 of the 14 tubes inoculated gave evidence of development. After the inoculation of the medium with the infected blood the tubes were sealed with paraffin or sealing wax and placed in a dark closet at room temperature. Six days later a drop of the water of condensation was examined and found to contain a number of very active trypanosomes, some that were languid, showing a tendency to agglomerate, and also many degenerated and inactive organisms. On each succeeding day the number of the latter seemed to be augmented, while the very active forms were rapidly decreasing, until the twelfth day, when the tubes showed numerous irregular granular bodies which were small, contracted, and rounded, representing degenerated forms of the trypanosome. Two days later small forms, about one-half the size of the adult organism, were observed gathered together in colonies containing from 4 or 5 to 20 or 30 individuals. These were actively motile, and by their appearance suggested a new generation of parasites. The smaller colonies were in several cases attached to a red blood corpuscle. No undulating membrane could be detected on the bodies of the parasites, and it was very difficult to determine whether these bodies were gathered together with their anterior or posterior extremity directed inward; in some cases, however, very fine filaments could be seen in the center of the colonies or rosettes.

These colonies increase in number and size until one clump, by the coalescence of numerous smaller groups, may contain several hundred closely packed wriggling forms of trypanosomes. The elements in these united clumps are arranged radially like the clusters of actinomyces. (See Pl. I, fig. 2.) Such large colonies are not frequent and are always irregular and usually elongate in outline. As they grow older some of the individuals become disengaged and wriggle around, frequently throwing their flagella about a red cell, and move about in a circle, but with less activity than is shown by the original organisms. The flagella appear usually longer than the length of the trypanosome's body. At times individuals are seen united in pairs by their posterior extremities. Many involution forms and bodies representing developmental stages may also be observed with an irregular nucleus, one or several vacuoles in the posterior extremity, and several small granular bodies at the anterior extremity. These organisms are of various shapes, from long, narrow, crescentic forms to short, thick bodies like tadpoles. Some of these organisms are inactive and are probably involution or transitional forms, while others are quite motile and represent the developmental stages. The nuclei of the former seem to be the first to alter their shape, assuming various peculiar positions and finally disappearing. The cell body then contains a number of small vacuoles scattered irregularly throughout its protoplasm. The protoplasm finally contracts into a spherical body or may disappear entirely, leaving the centrosome attached to the flagella and giving the appearance of a spermatozoan.

The growth of these protozoa in the blood-agar medium gave but slight microscopic evidence of development. No colonies appeared on the slanted surface of the medium, and the only indications denoting growth were a slightly increased turbidity of the water of condensation and a flocculent precipitate at the bottom which contained many bodies.

SEARCHING FOR THE TRYPANOSOMES.

After the trypanosome had been obtained and studied a mare and a Percheron stallion affected with the American form of the disease were shipped to Washington from the West in 1904. These animals, particularly the stallion, exhibited all the characteristic symptoms of the disease and were considered typical cases in which to find the trypanosomes. Blood was drawn from the animals two and three times weekly from both the veins and from plaques or urticarial swellings which appeared frequently on the stallion. On several occasions blood was drawn at midnight in order to insure the detection of the parasites in case they were only present in the circulation nocturnally. Without exception, however, no trypanosomes were found, and post-mortem examinations held on these animals were negative for these parasites in every case. Further, numerous experimental animals, including rabbits, guinea pigs, rats, mice, and dogs, were inoculated with small quantities of blood and various other fluids from the diseased horses, with negative results, and although in some cases death of the small experimental animals seemed to result from inoculation after a progressive emaciation lasting over a period of three to five months, the majority of these animals died of some intercurrent disease without showing any trypanosomes. From the fact that the trypanosome was found rather easily in the animals dead of the European disease, with the exception of rabbits, and that the most careful examination, microscopical as well as inoculation tests failed to show the parasite in the natural disease of this country until the 1911 outbreak of dourine in Iowa, it seems conclusive to the writer that the *Trypanosoma equiperdum* are fewer in number, less aggressive, and not as virulent in the dourine of the United States as they are in the countries where the disease is indigenous. In fact, the disease appears to be more acute and fatal in Asia and northern Africa than in Europe, and the *Trypanosoma equiperdum* at the same time are more easily detected, while in America the disease is even less acute and fatal than in Europe and the trypanosome even more elusive.

The technique used in finding the trypanosomes in the recent Iowa outbreak was to select a freshly formed plaque, from which the hair was shaved and the skin disinfected with carbolic acid followed by alcohol and distilled water. The skin over the plaque was next scarified with a sharp scalpel, as in human vaccination, until the serum commenced to ooze from the capillaries. A water-vacuum apparatus was then prepared in order to aspirate the serum from the plaque. An ordinary strong wash bottle was obtained, in the neck of which was placed a rubber cork with two openings containing a short and a long glass tube. The long tube was connected by rubber tubing to a funnel, which was held against the plaque, while the short tube was connected with a water-exhaust pump. A small cotton plug was left in the short tube of the wash bottle to prevent the return of unfiltered air when the exhaust apparatus was removed. The water was then turned on and the aspirating faucet slowly set to work in order that the exhaust would not be too great at the beginning. By this method the blood-tinged serum was readily drawn into the bottle and about 10 c. c. collected. This was subsequently centrifugalized and the upper layer of sediment examined in fresh smear preparations, with the result that trypanosomes were observed in limited numbers. They have always been very scanty and are only found after prolonged and tedious examination. Horse-meat bouillon, rabbits, and rats have been inoculated with the lower strata of this fluid, but thus far only the latter have revealed the presence of these protozoa.

INFECTIVENESS.

Material taken directly from infected horses seems to possess a very fluctuating virulence for small experimental animals. While in Algeria rabbits and dogs, as well as mice and rats, could be successfully infected, in Hungary the material from horses affected with dourine has only proved to be virulent for solipeds. Thus, as Marek has already pointed out, it seems that the virus has much more virulence in the southern than in the northern countries, or that it requires the injection of a large amount of fluid, which small experiment animals, as a rule, do not receive, in order to include a sufficient number of trypanosomes to produce the disease.

The fact that under natural conditions dourine is transmitted solely by coition causes it to differ from all other trypanosomiases, since the latter, so far as is known, are propagated by a biting insect, usually a fly, acting as a vector or carrier. Thus the trypanosome of dourine has the ability to penetrate the intact mucosa of the genital tract, whereby it reaches the blood, and, later, the more distant parts of the body. It takes its nourishment by osmosis and does not invade the blood cells. Its pathogenic action seems to result from the production of certain not yet determined poisons, which act first on the peripheral nerves and later on the general nervous system. A cellular infiltration of the nerve tissues develops, wherefrom the nerve fibers as well as the nerve cells degenerate and finally completely disappear.

Some authors are of the opinion that the disease has a more rapid and unfavorable course in stallions than in mares, while in asses the disease in most cases is confined to the local infection of the genital organs. Although the predisposition of solipeds to the infection is quite marked, not all stallions which serve diseased mares or all mares served by infected stallions contract the disease. According to Röll, about 66 per cent of the mares exposed to the infection become diseased.

A striking illustration of how a stallion may transmit the disease from an infected to a healthy mare without contracting the disease himself is given in the case of stallion 31. Frequent attempts were made to infect this horse through service with mare 30, affected with dourine, but without results. Finally, on June 4, 1902, the horse was allowed to serve a native Virginia mare (No. 32) shortly after coition with mare 30. This was repeated during the next five days. On June 20 the mucosa of the vulva of mare 32 was erythematous, and rabbits and guinea pigs were inoculated with the secretion without results. On June 29, when the mare was taken out of the stable for another service, her gait was noticed to be unsteady behind. She seemed to have a rolling motion from side to side, and it was thought that she would not have sufficient strength to support the male on her back. During the next few days she seemed nervous and to be falling off in flesh, although her appetite remained good. On July 5 the mare became acutely ill about 4 a. m. At 9 a. m. she went down on her side with head thrown back and back curved downward. She was completely paralyzed, being unable to regain her feet even with assistance. Her respiration was quite rapid, both abdominal and thoracic. Her abdomen was somewhat distended with gas and she passed a little gas constantly. Her eyes had a sunken appearance, but there was no perspiration apparent. There was a slight discharge from the vulva, the mucosa of which was extremely inflamed. The mare died at 6 p. m., and an autopsy was made the following morning.

The autopsy showed the heart to be normal, lungs congested, liver pale, yellow, and friable, kidneys slightly pale, spleen normal in size, with a few ecchymoses under the capsule. The posterior portion of the diaphragm was covered with fine white bands of fibrous tissue. The intestines were filled with gas, but otherwise empty. Small diffused extravasations of blood were noted under the serous membrane of the cecum and the large colon. The right ovary was enlarged, and softened with cysts. The left ovary appeared normal in size, but contained small cysts. The mucous membrane of the uterus was edematous and hemorrhagic in patches. The os was inflamed and the vagina contained edematous and hemorrhagic areas. The vulva was inflamed and contained one mucoid cyst and numerous petechial hemorrhages. The bladder showed cystitis and was lined with a yellowish exudate.

What effect the complicating attack of flatulent colic had upon the course of the disease is difficult to determine, but it is the only case in our experience of such short duration and with such acute lesions of the genitals. Inoculations of material from this mare into rabbits, guinea pigs, rats, and a dog were attended with negative results.

In order to compare the results obtained from the inoculation of material from a case of natural dourine with the disease produced by the injection of virulent material from France, the following experimental cases in equines are appended. These cases have brought

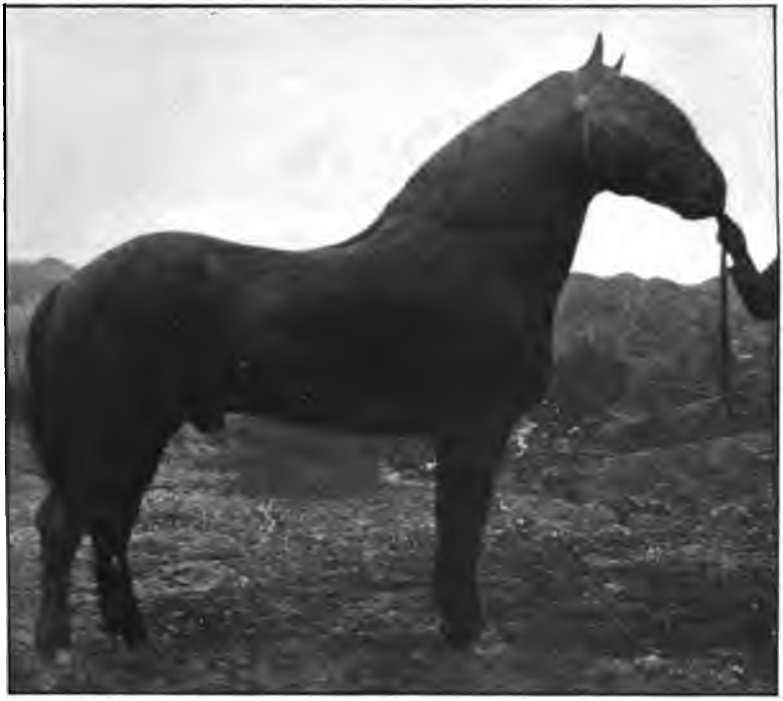

FIG. 1.—PERCHERON STALLION 42, SHOWING CONDITION AT THE TIME OF PURCHASE.

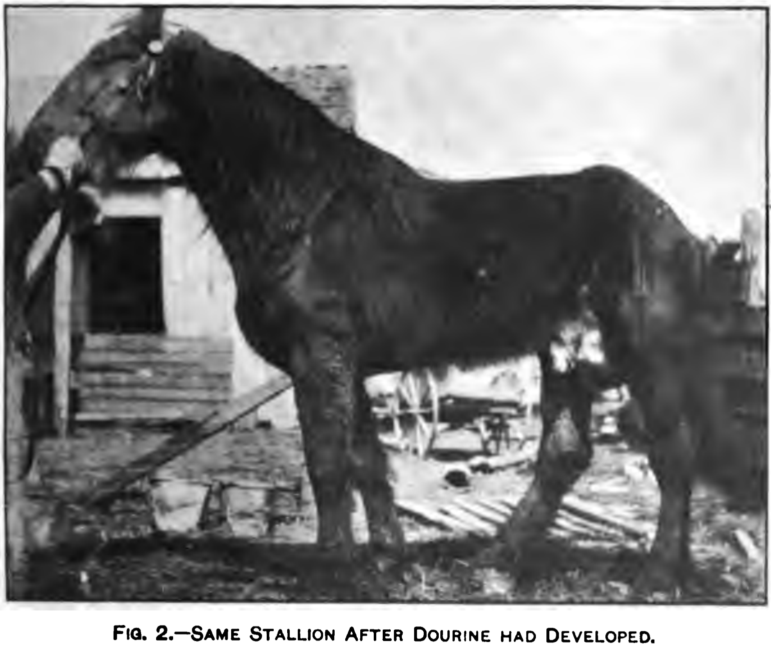

FIG. 2.—SAME STALLION AFTER DOURINE HAD DEVELOPED.

Spots on side and croup give location of plaques.

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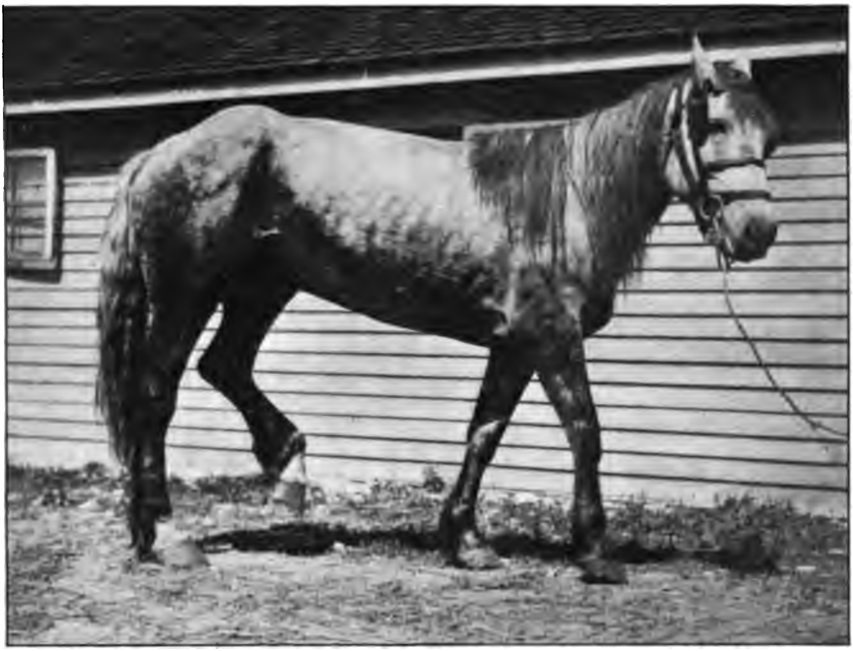

FIG. 1.—PERCHERON MARE 80, SHOWING CHRONIC DOURINE.
Observe the "tucked up" abdomen and emaciation having lost over 700 pounds in the previous four months.

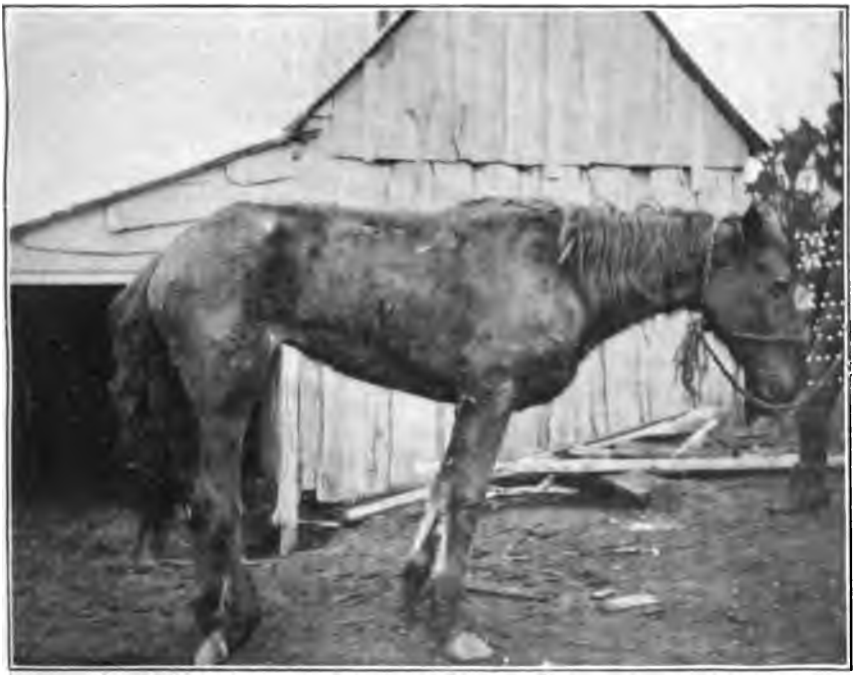

FIG. 2.—MARE 47 IN THE LAST STAGE OF DOURINE.
Notice the position of the off hind foot and the straightened hock joints.

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forward some interesting facts about the transmission of the disease, and may be divided into two series:

1. A case in which the American disease was transmitted by a stallion indirectly from an infected to a normal mare, which has been described above under the notes on mare 32.

2. Cases in which both the American and the European disease were transmitted by subcutaneous inoculations of infected blood.

In conducting the latter experiments a female ass was injected with serum taken from plaques which appeared intermittently on stallion 42. Before describing the results of these injections brief notes will be given of the symptoms and lesions manifested in this stallion.

STALLION NO. 42.

Black stallion received April 25, 1904, showing chronic symptoms of dourine. This case was one of the most typical that had come under our observation, and one of the few cases in which cutaneous plaques had been noted up to that time. His condition was very poor and showed considerable loss of coordination in the hind quarters. Several deep scars were noted on the penis, and the testicles were swollen. Plates II and III will give a good idea of his appearance before and after showing symptoms of dourine.

April 26. Stallion served mare 43 after she had been served by stallion 31.

May 2. Stallion served mare 43. A new plaque has appeared on left shoulder.

May 11. The plaque developing on left shoulder is now well developed, about 3 inches in diameter by one-eighth to one-fourth inch in height, and has a well-defined border.

An incision was made into plaque and blood drawn to inject rats and rabbits. Frequent inoculations of small animals were made with the contents of the plaques, but always with negative results.

May 12. The plaque noted yesterday seems to be slightly decreased. A new one about 1½ inches in diameter is forming back of right shoulder.

May 13. Stallion is losing in condition and is very hollow in flanks. The plaque on left shoulder is still present but is reduced in height. Three plaques are present on back of right shoulder. One plaque is forming in front of right shoulder.

May 14. The plaques are disappearing.

May 17. Stallion served mare 43 and then mare 36.

May 19. Has two small plaques on right side and one on left shoulder. The one in front of right shoulder is disappearing.

May 20. Served mares 43 and 36 in the same manner as on May 17. Has two small plaques back of left shoulder and two small ones on right side. The one in front of right shoulder from which blood was drawn has disappeared.

May 21. Has five small plaques on right side, one back of right shoulder, one back of and one on left shoulder; the latter is very small.

May 23. Has two plaques, one about 3½ inches in diameter, and the other about 2 inches in diameter, back of left shoulder, and one plaque about 3 inches in diameter on right side.

May 24. Has one plaque about 4 by 5 inches in diameter on left shoulder and one about 6 inches in diameter just in front of left flank.

May 26. Plaques have nearly disappeared. Animal is extremely thin. An attempt was made yesterday to have him serve mare 41, but he was unable to have an erection.

May 27. The plaques have about disappeared.

May 28. No plaques visible. Hind legs from hocks down are swollen. An attempt was again made to have him serve mare 41, but he was unable.

May 31. Has two small plaques on left hip. The hocks and below hocks are much swollen.

June 1. Stallion served healthy mare 41 to-day.

June 2. Has one plaque 4 inches in diameter on left hip, and one about 3 by 4 inches in diameter on right side. Legs from hocks down are still swollen.

June 3. Plaques same as yesterday, and hocks are much swollen.

June 4. The plaques are disappearing.

June 6. The two plaques noted on left hip several days ago have not yet entirely disappeared. No new ones present.

June 9. Plaque on left hip from which blood was last drawn is still present. The new one near root of tail has almost disappeared. No new ones.

June 10. Has two small plaques on back to the right of the spinal column.

June 11. The plaque from which blood was last drawn has disappeared. The two plaques noted yesterday are still present.

June 15. The two plaques noted on side are slowly increasing in size and height. A new one is beginning to develop on opposite side.

June 17. Plaques still present. Swollen condition of hocks has disappeared.

June 18. Has one plaque 2 by 4 inches in size on right flank, one about 2 inches in diameter on back to the right of spinal column, and one on left side.

June 20. Plaques same as noted yesterday, except that a new one about 1½ inches in diameter has formed on left shoulder.

June 22. The plaque on left shoulder is a little larger than on yesterday. One still present on left side. None present on right side.

June 24. Has three plaques on left side of back. Sheath somewhat swollen.

June 28. Has an edematous area 4 by 8 by 2 inches in size on chest to left of sternum. One plaque 2 inches in diameter in left axilla, one the same size in front of left shoulder (the hair has been rubbed from the surface of this one), one 1½ inches in diameter on left flank, one about 5 inches in diameter on left hip, and two small ones back of right shoulder.

June 29. Seems about the same as yesterday. An attempt was made to have this stallion serve mare 43, but while he had no trouble to have an erection he made no attempt to mount the mare, though she seemed very anxious to have him do so.

July 2. Has had a raw sore 1½ inches in diameter on right flank, which looks as though it might have been caused by rubbing. Has two small plaques on the chest to left of sternum. No other plaques visible. Appetite is good and he is in about the same condition as for some time past.

July 6. Has one plaque about 4 inches in diameter on left hip; three very low ones, each about 1½ inches in diameter, in front of left shoulder; one about 3 inches in diameter back of right shoulder. Animal seems to be holding his own.

July 11. Has one plaque about 4½ inches in diameter back of left shoulder and one about 2½ inches in diameter on left hip. The sore on right flank, noted some time ago, does not heal and now has an unhealthy appearance.

July 16. No plaques visible. Sore on right flank healing. Condition of animal is poor, but he seems to be holding his own.

July 23. Losing in condition. Has one plaque about 2½ inches in diameter on left hip.

July 27. Has a plaque about 3 by 4 inches in diameter on right hip at root of tail; this was noticed for the first time yesterday afternoon. The one noted on left hip some time ago is still present and is about 4 inches in diameter.

August 3. Plaque on left hip still present; shape and size changes from day to day. The one on right hip from which blood was drawn has disappeared.

August 9. Plaque on left hip still present. No new ones. Condition of animal is very poor, but he has a good appetite and is bright.

September 10. One plaque has appeared on left lumbar region.

September 20. Donkey 34 injected subcutaneously in left side of neck with 10 c. c. of blood drawn from a plaque on left hip.

(NOTE.—This donkey is to be injected whenever suitable plaques appear on stallion.)

Stallion has three plaques on each hip, each in size from 2 to 3 inches.

September 30. Hind legs much swollen, also scrotum and sheath. Several plaques on thighs.

October 3. Plaques have almost disappeared. General condition very poor.

October 5. Has been down since yesterday morning, and is helpless. Respiration very much accelerated.

Forty cubic centimeters of blood drawn and used to inject donkey 34.

October 6. Still lies stretched out, and respiration is quite rapid.

October 7. Found dead this morning.

The temperature of this animal taken twice daily since April 26 shows a range between 101° and 102.8° F. Many microscopic examinations of the contents of the plaques failed to reveal any trypanosomes.

The post-mortem examination showed that the carcass was very emaciated and anemic, and would probably weigh not more than 1,100 pounds. Several small bed sores were observed, involving the skin and underlying tissues in the region of the pelvic prominences and the elbow joint. On skinning, the hide seemed dry and tough, and in the region of the gluteal muscles of the right side three yellowish gelatinous areas with injected blood vessels were seen, about the size of a quarter, which represented the location of the last observed plaques. On the dependent (left) side of the carcass the subcutaneous tissues were infiltrated with a thick layer of coagulated serum that had exuded from the blood vessels. The great dorsal muscles on both sides of the spine in the lumbar region were softened, swollen, and contained numerous small hemorrhagic areas. On opening the thoracic cavity both lungs were found to be edematous, while the left was also engorged with blood as a result of hypostatic congestion. The heart was normal and contained black, feebly coagulated blood. The liver appeared normal with the exception of several small yellowish areas of necrosis, probably of parasitic origin. The spleen was slightly shrunken and showed numerous pin-point hemorrhages under the capsule. The right kidney was apparently without lesions, while the left organ was hypostatically injected. The stomach contained a small number of bots, while the large intestine showed several small hemorrhagic points, the result of the 40 or 50 sclerostomes which it harbored. The spinal cord in the lumbar region contained many petechial hemorrhages, while the meninges were slightly inflamed. There was also an excess of serous fluid in the spinal canal. The penis showed many depigmented areas of irregular shapes and sizes, but at least two of these patches were raised, hard, and dense, resembling cicatricial tissue. The urethra was normal.

The testicles were atrophied somewhat and slightly denser in consistency than normal. The tunica vaginalis of both testicles showed 17 hemorrhagic patches of projecting villi and 2 or 3 warty neoplasms were present on the tunica propria. At the apex of the testicular sac on the right side a large diffused hemorrhagic patch was observed, with several fibrous bands adhering to the testicle. This sac also contained an excess of yellowish transparent fluid exudate.

It is interesting to note in connection with this case that although neither of the healthy mares which were served by this stallion contracted dourine, and the injection of numerous dogs, rats, rabbits, and guinea pigs resulted negatively, nevertheless serum taken from the plaques and blood from the jugular when injected subcutaneously into donkey 34 produced the disease, but did not show any trypanosomes. The notes on this donkey follow.

DONKEY NO. 34.

September 20, 1904. Injected subcutaneously in left side of neck with 10 c. c. of blood drawn from a plaque on left hip of stallion 42.

October 5. Injected subcutaneously in front of left shoulder with 60 c. c. of whole blood drawn to-day from jugular of stallion 42.

October 7. A firm swelling 10 inches in diameter by 3 inches high is noticed at seat of injection.

October 18. No abscess has formed at seat of injection, but there is still present a very firm enlargement about 3 by 3 by 1 inches in size.

November 19. Vulva somewhat swollen. Mucosa of vagina reddened. Animal has a patch of edema about 6 inches in diameter by 1 inch high on abdomen. The skin over an area 4 inches in diameter at seat of injection is indurated. These symptoms were first observed November 16.

November 28. Vulva still swollen; vagina congested. Edema on abdomen has almost disappeared. A hard spherical nodule about 1½ inches in diameter is seen about 6 inches below seat of injection. This is firmly adherent to the deeper structures but not to the skin.

December 2. Swelling of vulva is increasing slowly.

December 6. Vulva still swollen and vagina congested. Many small eruptions on shoulders and withers, which cause the hair to fall out in patches.

December 10. A patch of edema about 6 by 14 by 1 inches in size over sternum and abdomen; loose tissue in left flank edematous, and left inguinal lymph gland somewhat enlarged. Vulva is still swollen. The eruptions on sternum same as on withers. Nodule in front of left shoulder same as last noted.

December 12. Edema on flank is slightly reduced; that on abdomen same as last noted. Vulva still swollen. Mammæ slightly edematous. Eruptions on skin still present.

December 20. Vulva much swollen. Eruptions on skin increasing.

December 29. Animal has a large patch of edema about 1 inch in height extending over ventral aspect of body. Vulva still swollen.

January 7, 1905. Edema over ventral aspect of body. Vulva much swollen. Area of edema in left flank.

January 10. Vulva very much swollen, also hips for a distance of 5 or 6 inches to either side. Nodule in front of shoulder is still present. Only a small amount of edema on aspect of body or in left flank.

January 11. About 350 c. c. blood drawn from right jugular; 60 c. c. of this was injected immediately into left jugular of donkey 37; the balance was defibrinated, and 60 c. c. injected intravenously into donkey 43. (See records of donkeys 37 and 43.)

January 12. Swelling of vulva and hip not nearly so great as it was yesterday. No edema over ventral aspect of body. Many eruptions still present on shoulders and back. Appetite not as good as usual.

January 13. Vulva swollen about the same. Hips for a distance of 5 or 6 inches around vulva much swollen. Appetite better.

January 16. Swelling of vulva slightly reduced; that of hips has increased slightly.

January 20. Swelling of vulva increased a little over what it had been for the past few days. No change in swelling of hips. A hard nodule about 3 cm. in diameter has appeared at point about 5 cm. to left of anus.

January 23. Swelling of vulva increased.

January 31. Animal has an enlargement about 3 inches in diameter by 2 inches in height immediately to left of anus. This enlargement has a hard sensitive border and a soft center about 1 inch in diameter. The vulva is still swollen and edema is still present on rear of thighs and in left flank. Nodule in front of left shoulder still present.

February 1. Abscess which has formed at side of anus is broken and is discharging sero-purulent fluid.

February 2. Abscess has discharged all of its contents. Swelling and skin lesions are about same as last noted.

February 11. Has a patch of edema about 4 by 5 by 1 inch between forelegs. Vulva and tissues surrounding it much swollen. Abscess completely healed.

February 17. Vulva and rear of thighs much swollen. Considerable edema over abdomen and between forelegs. Many small eruptions over neck and shoulders. The hair in this region has fallen out.

February 20. Same as last noted, and in addition a plaque 2 by 3 inches in area on left side of neck.

February 21. About same as yesterday.

February 23. Skin disease lesions still present and spreading. Enlargement in front of left shoulder increasing in size. Edema still present between forelegs and abdomen. Vulva still swollen.

March 8. Portion of hips still swollen. Vulva and loose tissue below it are swollen. Enlargement in front of left shoulder increasing in size. Small enlargement at seat of blood injection.

March 17. Edema between forelegs and over abdomen. Vulva and loose tissue between it and udder edematous. Enlargement in front of left shoulder same as last noted.

April 1. Udder and vulva swollen.

April 10. Same as last noted.

May 5. Vulva and udder still swollen.

May 16. Vulva slightly swollen. Swollen area one-half to 1½ inches high and 16 inches in diameter surrounding anus and vulva. Both prescapular glands enlarged.

May 25. Prescapular glands still enlarged. Edema in inguinal region. Vulva and hips swollen.

May 29. Hips and vulva slightly swollen. No plaques visible.

June 15. Animal seems to be recovering. Highest temperature noted, 102.4° F.

July 15. Apparently well.

August 15. Apparently well.

September 18. Gave birth to a normal male colt.

October 10. Served by male donkey 48 to-day, and on four previous occasions, without infecting the male.

May 18. Killed to-day. All organs normal.

As already mentioned, the blood of donkey 34 was injected into donkeys 37 and 43 on January 11, 1905, the first receiving the whole blood, while the latter received the filtrate. The records of these donkeys which follow show that the virus was successfully held back by the Chamberland filter.

DONKEY No. 43.

January 11, 1905. Injected into right jugular with 60 c. c. of filtered blood of donkey 34. This blood was drawn at 10 a. m. to-day, was defibrinated, diluted, filtered, and injected at 4.30 p. m.

Animal is now in fairly good condition and seems to be well in every respect.

May 29. Up to this date has shown no symptoms, and temperature has not exceeded 100.4° F.

December 9. Served by donkey 48 (by mistake).

December 26. Female foal born to-day.

January 11, 1906. Foal and dam killed. No lesions.

DONKEY No. 37.

January 11, 1905. Injected into right jugular with 60 c. c. of whole blood of donkey 34.

January 23. No symptoms of disease.

January 25. Animal has a plaque about 3 inches in diameter by ½ inch in height on left hip a short distance from root of tail.

January 28. Plaque on hip still present. No other lesions.

February 11. Plaque has almost disappeared.

February 17. The plaque on rear of left hip is now about 5 inches in diameter by 1 inch high.

February 21. Superior portion of neck is much swollen. Patch of edema between forelegs. Edema on thigh still present.

February 23. Skin eruptions of shoulders; hair beginning to fall out; enlargement about 3 cm. in diameter on front of left shoulder, and a patch of edema between forelegs.

February 24. Vulva swollen, in addition to symptoms noted yesterday.

March 2. An enlargement about 4 cm. in diameter is noted at right of vulva.

March 8. Animal has eruption on neck, and vulva swollen a little.

March 17. Swelling of vulva has nearly subsided. Legs in region of hock swollen.

March 23. Large patch of edema 1 to 1½ inches in height extending over sternum and abdomen. Vulva only slightly swollen.

April 1. Vulva swollen somewhat. Edema still present on abdomen but reduced in height. Left prescapular gland is enlarged.

April 4. Vulva swollen. No edema on abdomen.

April 15. Same as last noted.

April 20. Vulva much swollen. Mucous membrane in region of os uteri is edematous.

May 5. Large patch of edema on chest and abdomen. Vulva swollen, also the tissue between it and the udder.

May 8. Vulva swollen, an edematous ridge 1½ inches wide by 1½ inches high extending from vulva to a point on left side of udder where it broadens out into a patch 3 by 4 inches in area. Large patch of edema on abdomen; small abscess formed and broken over posterior surface of knee; left front leg swollen, and a shallow ulcer on anterior surface of hock.

May 9. Right foreleg swollen, pits on pressure, discharging abscess at posterior portion of knee joint. Vulva much swollen; its mucous membrane presents a somewhat granular appearance; swollen ridge noted yesterday is still present.

May 10. Has a slight vaginal discharge; has a plaque about 4 by 3 inches by ½ inch immediately in front of left flank.

May 11. Plaque noted yesterday is still present, and one about 3 inches in diameter by one-half inch high is present a short distance above and in front of it. A third one about 2 inches in diameter by ½ inch high on left hip. Swelling on left front leg is subsiding. Abscess on knee is still discharging.

May 12. Plaques about same as noted yesterday.

May 17. Abscess on left knee is still discharging sero-purulent fluid, which has a very bad odor. This leg is swollen between knee and ankle; both prescapular glands are enlarged; vulva only slightly swollen with very little discharge. Several plaques on body.

May 24. Has patch of edema between forelegs. Vulva still swollen, and plaques seem to be disappearing.

May 25. Vulva only slightly swollen. A new plaque has appeared in left inguinal region, and old ones have not altogether disappeared.

May 29. One old plaque is still present on left side; others have disappeared. Abscess on knee still discharging. Vulva still swollen.

May 31. Vulva is very much swollen. Left hind leg swollen. Old plaque on left side is still present and several new ones have appeared.

June 1. Vulva much swollen. Swelling on knee reduced. Abscess still discharging, and an extensive patch of edema on abdomen.

June 3. Has a large amount of edema on abdomen and between fore legs. Abscess still discharging. Ulcers on hocks. Vulva still swollen.

June 5. Only a small amount of edema on abdomen; abscess not discharging; a few plaques still present; vulva only slightly swollen.

August 3. Several small plaques present. Highest temperature recorded, 102.2° F.

September 10. Gave birth to a healthy male colt.

October 12. Served by male 48 to-day, and three additional times since September 21, without infecting him.

May 18. Killed to-day. All organs normal.

Mare 33, suspected of being in foal, was inoculated on November 4, 1903, with material containing trypanosomes obtained from the dog imported from France. Two inoculations were made, 5 c. c. being used subcutaneously in front of left shoulder and 5 c. c. subcutaneously into the left hip.

MARE NO. 33.

November 8. Has a soft sensitive swelling about 4 by 6 by ½ inches in size at seat of injection in front of left shoulder, and a very flat sensitive swelling about 5 inches in diameter on left hip.

November 9. The swellings on hip and in front of shoulder have become much smaller.

November 11. The swellings have increased, are hard and very sensitive. The one in front of left shoulder is about 4 by 5 by 1 inches in size, and the one on left hip is about 8 inches in diameter by ½ inch high.

November 12. The swellings are about the same as yesterday.

November 16. The swellings have almost disappeared. No lesions to be seen elsewhere.

November 20. The swellings have disappeared.

December 1. Has a patch of edema about 6 by 8 by 1½ inches in size between the forelegs; also has some edema over the abdomen. Udder enlarged. Hind legs below hocks are edematous. No swellings at seats of injections. Animal seems to be well otherwise.

December 2. Has a sharply defined patch of edema about 2 inches high which extends over almost the entire sternum and abdomen. The legs are edematous. No lesions at seats of injections or in vagina. Animal seems to be well otherwise.

December 3. Same as yesterday.

December 12. Edema about 2½ to 3 inches in height and extends over entire sternum and abdomen. No lesions to be seen in vagina. Animal otherwise appears normal.

December 15. No further reduction in amount of edema. Animal seems to be well.

December 23. Still has considerable edema over abdomen.

December 30. Has been quite lame in left hind leg for several days past. Edema over the sternum is slowly disappearing.

December 31. The edema is nearly gone. Animal is still quite lame, but appetite is fairly good.

January 2. The edema has entirely disappeared from sternum and abdomen. The lameness is slowly disappearing and health seems to be good.

January 6. Very lame in left hip; can bear no weight on this leg, which seems to be very painful. Mare seems to be well otherwise. No lesions to be seen in vagina.

January 8. Leg seems to be more painful than ever, so much so that she will not stand up long enough to eat all of her morning feed.

January 11. Seems unable to remain on her feet but a few minutes at a time, but appetite is fairly good.

January 12. Lameness is slowly becoming worse, and right hind leg seems to be affected also. Appetite seems to be fairly good, but she does not seem able to stand on her feet long enough to eat very much.

January 15. Unable to get up without assistance, and can not stand owing to weakness in lumbar region. Appetite is good. Mucous membrane of vulva is injected.

January 18. Mucous membrane of vulva and vagina very much congested. Animal unable to get up, lies stretched out and seems to be in considerable pain, but holds head up to eat and has considerable sticky muco-purulent vaginal discharge which contains a few trypanosomes. Temperature is commencing to rise; 103.2° F. at 9 a. m., 103.8° F. at 5 p. m.

January 20. Animal considerably weaker than heretofore; has very little appetite, and a profuse yellowish discharge from vagina, which is still much congested. Rabbits and rats inoculated with this discharge showed the presence of numerous trypanosomes.

January 21. Little change since yesterday, but mare is weaker.

January 22. One sharply defined patch of edema about 4 by 3 by 1 inches in size on opposite side to that on which the animal is lying.

Is much weaker than she has ever been; respiration accelerated; does not take notice of anything. Temperature at 8.30 a. m., 105.6° F.; at 10 a. m., 106° F.; at 1.30 p. m., 106.4° F.

Has several bed sores which have an offensive odor. Wounds made over jugular for drawing blood do not heal.

Found dead about 4.20 p. m.

The post-mortem examination showed the animal to have fallen off gradually in flesh. The skin contains several bed sores involving the adjacent muscles. The heart is normal; left lung hypostatically congested; liver enlarged and friable; kidneys softened, pale, swollen, and contain a few extravasations; spleen darkened, enlarged, and shows several petechiæ under the capsule; uterus contains an 8-months fetus, which is apparently normal; vagina is edematous, with a gelatinous infiltration of the mucosa; vulva appears swollen and slightly congested, with a gelatinous exudate adhering to its walls.

The left coxo-femoral articulation shows a roughened erosion on the acetabulum one-eighth by one-third of an inch in size, while the head of the femur contains a similar ulcerated area, which no doubt was the cause of the pain and lameness in this leg.

Many smear preparations were made and various small experimental animals were injected at different times with material from this mare, and although the trypanosomes were elusive and at times exceedingly difficult to find, they nevertheless were usually located.

SYMPTOMS.

There are many variations in the symptoms of dourine, and this is particularly true of the disease as it occurs in this country. In order to give a fair idea of the "symptom complex" it will be necessary to describe manifestations which may appear in a number of horses, it being understood that each individual may have several but not all of the symptoms enumerated. Two distinct stages may be noted, which vary somewhat from those described in textbooks, but probably no more than could be expected when differences of climatic conditions and methods of handling are taken into consideration.

The first stage chiefly concerns the sexual organs, and therefore differs somewhat in the male and female. In the second stage symptoms indicating an affection of the nervous system are more prominent and are not dependent on the sex of the animal.

Following a variable period of incubation of from eight days to two months, there is seen in the stallion an irritation and swelling about the penis first noticed in the glans. This swelling extends throughout the organ, and the penis may be continually protruded and frequent erections noticed. The edematous swelling also involves the groin, with enlargement of the adjacent inguinal glands, and extends forward along the abdomen. In a few days small vesicles or blisters appear on the penis, which break, discharging a yellowish serous fluid and leaving irregular raw ulcers. Where primary ulcers are in proximity to each other there is a marked disposition to coalesce, a large raw surface with an irregular border resulting. The ulcerative process may form a wound extending almost entirely around the penis. The ulcers show a tendency to heal rapidly, leaving white cicatrices or scars which are permanent. In some cases the urinary meatus is very red and swollen, and according to some observers, especially European, more or less of a thick catarrhal exudate is discharged from its orifice. This condition, however, has been rarely seen in cases in this country, a more or less continuous dripping from the urethra of a yellowish, serouslike discharge alone being present. The stallion retains his full genesic instinct and becomes very amorous when brought in the vicinity of mares. If allowed access to mares in season, service is often impossible, due to the fact that a complete erection of the penis does not occur. The testicles may be involved and tender to pressure, and abscess formation may occur, with sloughing.

In the mare the first symptoms may be so slight as not to be noticed by the owner. This is especially so where the mares are running on the open range and not seen by the owner for long periods. In fact, the first knowledge in such instances frequently comes from finding a diseased mare astray in the foothills, having been driven out of the band by the stallion. This custom of getting rid of undesirable or diseased mares is quite general with the leader of a harem of mares running at large in distinct bands on the western ranges. However, the disease, being the result of copulation, begins with swelling and inflammation of the vulva and vagina. The labia are continually everted, exposing the clitoris, which is constantly in a state of erection. There will also be a muco-purulent discharge like that coming from the penis of the male, which may be slight or profuse in quantity, agglutinating the hairs of the tail. The mare will switch the tail, appear uneasy, and urinate frequently. Shortly papules and vesicles appear on the external vulva, as well as on the mucosa of the vulva and vagina. These vesicles soon rupture, but before doing so the contents undergo a change from a transparent to a purulent fluid. The rupture of these pustules is the initial stage in the formation of deep, angry ulcers. These ulcers show a tendency to heal rapidly, but invariably leave a cicatrix, which is permanent, causing a slight puckering of the tissue. On the dark skin on the external vulva the scars will always be white, more or less circular in outline, from one-eighth to one-half inch in diameter, and pitlike, similar to the depression in a pockmark. This depigmentation of the skin about the external genitals, due to healing of the ulcer, is permanent and not temporary, as in coital exanthema and other affections simulating it. Edematous infiltration of the perineum and the mammary gland frequently occurs.

Sometimes, and especially in the mare, the above-described lesions tend to disappear gradually, and in case the mare is not served again the disease may remain in abeyance for months or a year. The apparent recovery, however, is not permanent, and any excessive work or excitement, and especially being served by a stallion, even if he be healthy, may set up the disease anew. In case an affected mare conceives, she is liable to abort at any time during her term of pregnancy. When the fetus is carried to full term, it occasionally is a weak and imperfectly developed foal; but in this country many fine colts have been born to affected mares.

The nervous or constitutional disturbances of the second stage may not come on for months or even a year after the appearance of the local lesions, and are similar in both male and female. They consist

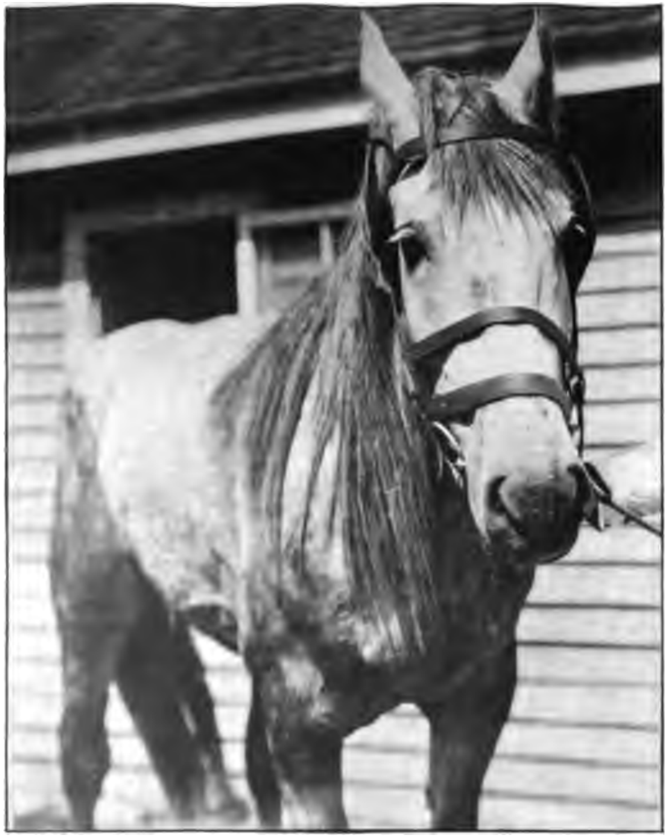


FIG. 1.—MARE 80, AFFECTED WITH DOURINE, SHOWING PARALYSIS OF THE RIGHT NOSTRIL.

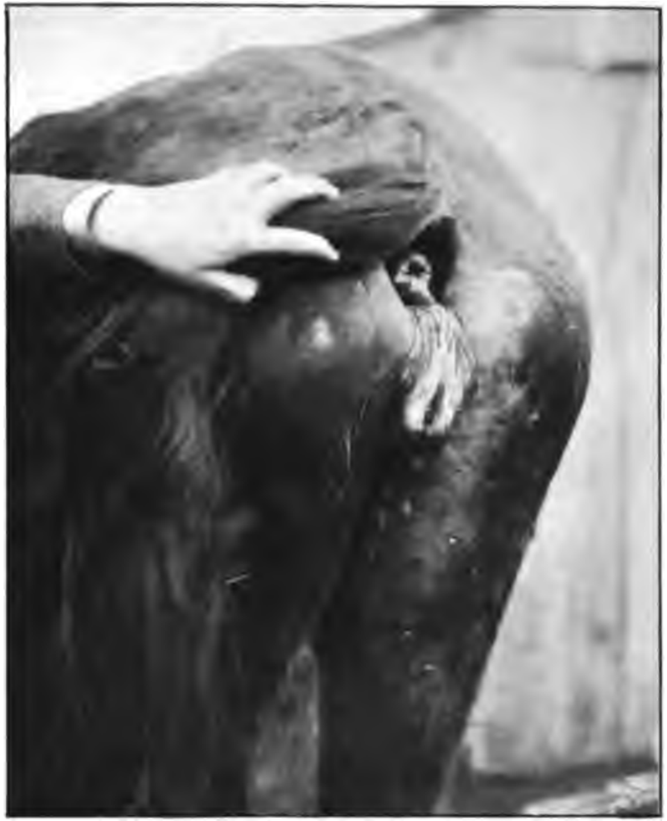
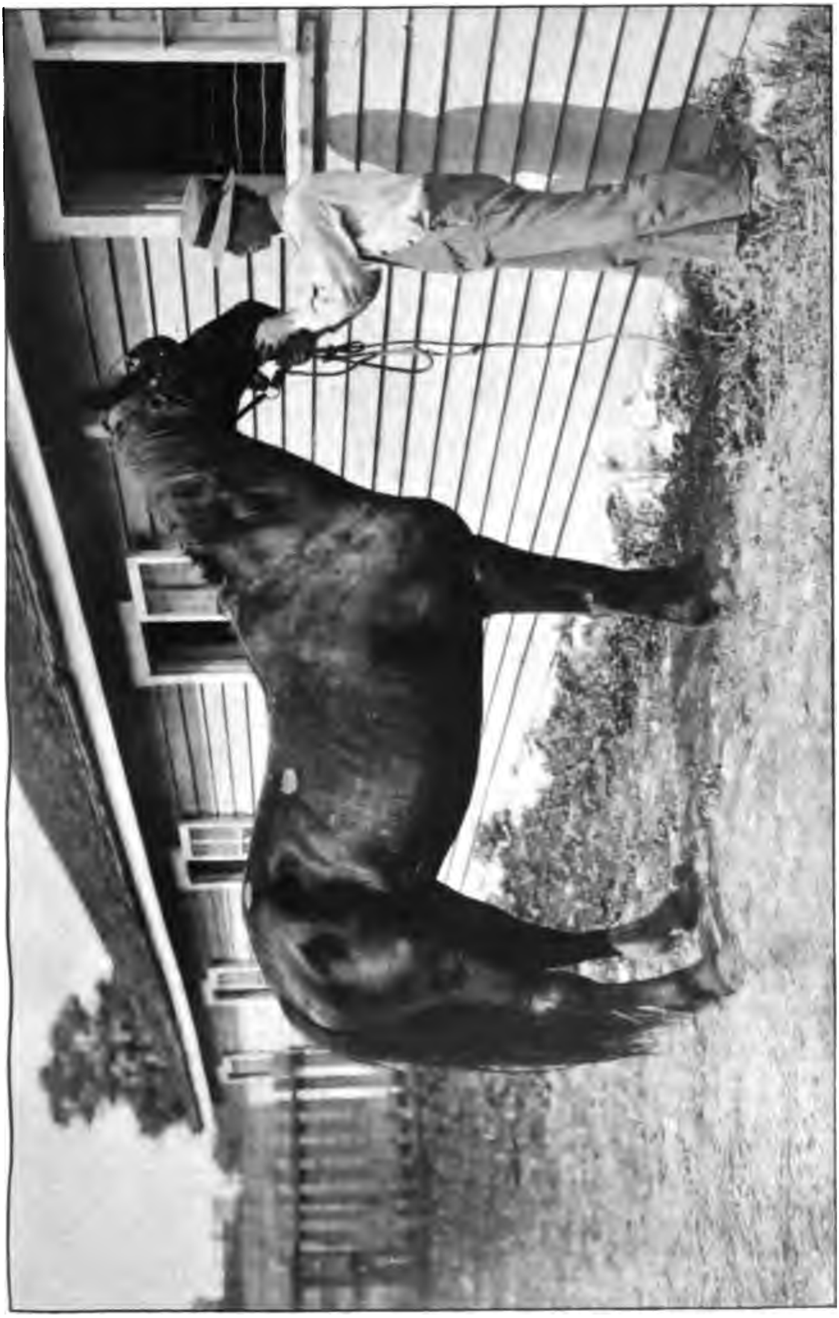


FIG. 2.—LESIONS OF DOURINE INVOLVING THE EXTERNAL GENITALS AND PERINEUM OF MARE 47.

Note the areas of pigmentation.

UofM



MARE 79, BRED TO AN IMPORTED STALLION MARCH 7, 1911, AND DEVELOPED EVIDENCES OF DOURINE 15 DAYS LATER.

Note the plaques on the croup, back, shoulder, and abdomen, from the latter of which the first trypanosomes were obtained.

of a general nervous disorder with staggering, swaying gait, especially in the hind limbs. The animal becomes extremely emaciated, particularly in the hind quarters, and the abdomen assumes a "tucked-up" appearance. (See Pl. III, fig. 1.) The first indication of paralysis will be noted in traveling, when the animal fails to pick up one of the hind feet as freely as the other. There is a tendency to drag the foot partially, which will wear off the toe more than normal. This condition may shift from one hind foot to the other, or both may become affected simultaneously, at which time knuckling is a common symptom. (See Pl. III, fig. 2.) Only occasionally are the nerves of the front extremities and the face affected, the latter finding expression in paralysis of an ear, eyelid, nostril, or lip. (See Pl. IV, fig. 1.) Twitching of the superficial muscles has also been noted in several instances. Urticarial eruptions or plaques may break out over various parts of the body. These swellings, which prior to the recent Iowa outbreak had been observed in only a few cases in this country, disappear in a few days, only to reappear at some other point. In the outbreak just referred to almost every horse showed two or more plaques. They are sharply defined, round, flat, edematous infiltrations of the papillary layer of the skin, about the size of a half dollar, or may be even larger. Some have a depressed center and an elevated periphery. When punctured, a bloody serum exudes from the cut surface. The usual locations of these plaques are the croup, belly, and neck. (See Pl. V.) There may also be noted pruritis of the skin, which causes the animal to rub itself frequently. White spots appear on the hind legs and in the region of the perineum, as a result of the discharge from the penis and vagina coming in contact with and causing a depigmentation of the integument. (See Pl. IV, fig. 2.) The temperature of the animal seldom goes above 101° or 102° F. Labored breathing is occasionally noted. In some cases the glands under the jaw swell and a discharge appears from the nostril simulating glanders. When the paralysis of the hind limbs starts to appear, it usually progresses rapidly, the horse goes down, is unable to rise, and dies in a short time from nervous exhaustion. Up to the last, however, the appetite remains good, and the stallion will show a desire for the mare, although service is impossible, as the horse can neither get a complete erection nor raise himself on his hind legs.

POST-MORTEM LESIONS.

On autopsy there are noted swelling and gelatinous infiltration of the mucosa of the vulva and vagina, together with marked hyperemia. The uterine mucosa is thickened, infiltrated, and corrugated, resembling the mucous membrane of the large intestine in Johne's disease. Ulcers are sometimes present, although rarely so in the disease as it exists in this country. The mucous membrane is not infrequently of an orange-colored hue, covered with a muco-purulent exudate and occasionally supports small, irregular yellowish patches of mucoid degeneration. The ovaries are frequently involved, and their parenchyma may be the seat of hemorrhage and large blood clots may be found within their capsules. The skin in the region of the perineum where the discharge has come in contact with it is depigmented, leaving irregular white patches. In the male the penis is usually found to be enlarged, although in some cases it is normal in size. It frequently contains ulcers and scar tissue both on its surface and in urethral canal. The sheath is also tumefied and the skin thickened. The testicles in some cases are soft and atrophied, while in others just the opposite is found. Adhesions may occur between the tunica vaginalis and the tunica propria. In nearly all cases the scrotum is more or less infiltrated. The lymphatic glands in the inguinal region are also inflamed, and in many cases may be plainly visible as irregular wavy lines under the skin. There is also a yellow gelatinous exudate beneath the skin in those areas where plaques were situated just before death. In cases of long duration there is more or less marked atrophy of the muscular system, a condition naturally following the paralysis which precedes death.

The changes in the spinal cord have been principally studied by Thanhoffer. The meninges, especially the pia mater, are severely congested; in some places adhesions have taken place between the pia and the cord, while in others the pia is severely congested. The central canal in the spinal cord is dilated in certain points and may contain an excessive quantity of fluid. On section softened areas may be found in the substance of the cord, and dark red spots may also be present, indicating hemorrhage. The supporting framework of the spinal cord (neuroglia tissue) is hypertrophied, especially around the central canal, producing sclerosis, or hardening of the cord. The large spinal nerve cells are involved, and the nuclei frequently undergo granular disintegration. In other cells the axicylinder process is affected and its outline is wavy and tortuous. According to Marek, the change observed in the nerves is a polyneuritis. The ventricles of the brain also contain an excessive amount of fluid. In summarizing, we may say that there is a general hydrops of the central nervous system with a tendency to degeneration in the spinal cord, and multiple hemorrhage formation in the substance of the cord with slight leucocytic infiltration. The skeleton is also affected, and the bones may be softened. The medullary substance (marrow) is congested, and hemorrhages and erosions may be seen on the articular cartilages of the joints. A discoloration of the synovia, due to red blood cells, is frequently seen, giving it a peculiar pinkish coloration.

The intestines usually contain but small quantities of alimentary matter, and ulcers may sometimes be found in the mucous membrane. The peritoneum is hypertrophied and has a yellowish cast, due to the serum it contains in its meshes. The mesenteric and inguinal lymph glands may be enlarged and softened or small and firm in consistency. The liver contains areas of fatty degeneration, is severely congested, and may contain minute hemorrhages in its parenchyma. The spleen may also contain these petechia, but it is usually only slightly enlarged, soft, and doughy, although it may be normal in size and appearance in the horse. In experimental animals, however, and particularly white rats inoculated with trypanosomes, this organ is enlarged to two to three times the normal and very severely congested.

The kidneys are enlarged and soft in consistency and show the presence of parenchymatous degeneration. The lungs are almost invariably very much congested, and suppurative foci may sometimes be found in their substance. The blood is watery and forms imperfect soft clots, the red blood cells having undergone extreme diminution in number, although there is a decided leucocytosis with a marked increase in the quantity of lymphocyte cells.

COURSE OF THE DISEASE.

The course of the disease, as will be seen from the symptoms, is extremely variable, and may cover a period ranging from nine months to two years. At the commencement of the attack the genital symptoms alone are observable. These, however, sooner or later become complicated by the appearance of the systemic or nervous disturbances, including loss of flesh, staggering gait, and paralysis of the posterior extremities. These symptoms gradually become intensified until the animal, reduced to skin and bone, is unable to rise, and death at last results from exhaustion, lack of nutrition, or from septic infection. This course is markedly influenced by the condition and environment to which the animal has been subjected. Bad weather, exposure, insufficient food, and complicating diseases like influenza, distemper, or in fact any condition which tends to lower the vitality of the animal, will hasten the termination of the disease. On the other hand, good care and abundant food will prolong life, and in this country has even resulted in recovery. It is also possible under favorable conditions that an animal may have dourine in the latent form for several years without manifesting any alarming symptoms and yet be a source of danger.

PROGNOSIS.

Although now and then a case of dourine may recover, as a rule the disease is present merely in a latent state, and the excitement caused by copulation is very likely to cause it to reappear with renewed vigor. The outlook, therefore, from a prognostic point is always to be considered unfavorable, and in a country where a relatively small number of cases appear temporizing methods of suppressing the disease are not warranted.

DIFFERENTIAL DIAGNOSIS.

In countries where dourine is the only infection caused by trypanosomes, the diagnosis is made certain by the demonstration of these parasites; but, as has already been noted, this is connected with considerable difficulty, as the parasites in the blood appear very seldom and then only in small numbers. They are most constant in the serous fluid of the cutaneous plaques and in the edematous swellings and muco-purulent discharges of the vagina, but even here they appear only periodically. While it is a comparatively easy task to diagnose the disease in its acute form if ulcers are present on the genitals and edematous patches on the skin, those cases which have apparently recovered, or which may more properly be termed chronic, present many difficulties. The diagnosis is much easier if several animals are affected at the same time.

Coital exanthema or vesicular exanthema is the disease most frequently mistaken for dourine, as both appear shortly after the act of copulation with nearly similar symptoms. During the ulcerative stage and without a history of the case, it is somewhat difficult to make a differential diagnosis. However, the period of incubation in coital exanthema is shorter, the ulcers produced by the ruptured vesicles are more superficial and heal more rapidly, the resulting depigmention is only temporary, and permanent scars on the mucosa of the genitals are not observed, neither does it cause abortion or terminate in paralysis.

At times the initial stage of dourine is confounded with a traumatic inflammation of the genital organs. However, the traumatic origin may easily be excluded, on the one hand, through the lack of observable lesions; and, on the other, through the character and persistent continuance of the edematous swelling.

The plaques of dourine are similar to urticaria, but in the latter disease lesions of the genital tract and nervous symptoms are absent, and there is no evidence of contagion.

The paralysis of the hind quarters is only characteristic for dourine when taken in connection with other nervous symptoms. Among other diseases showing a similar paralysis may be mentioned azoturia, forage poisoning, and swamp fever, but these diseases are as likely to affect geldings as stallions or mares. They may also be discriminated from the paralysis of dourine mainly through the absence of lesions of the sexual organs. In the latter disease the accessory conditions, such as the infection of several animals shortly after the act of copulation, as well as the different aspect of the symptoms in the affected animals, offers a sufficient foundation for a correct diagnosis.

Although the vaginal discharge of leucorrhea may resemble that of dourine, the characteristic ulcer or cicatrix of dourine is always absent. The nearest approach to it is a raw and abraded condition of the lips of the vulva due to the irritating properties of the discharge. Nervous symptoms terminating in paralysis are not observed.

On the western range it is not unusual to see several stallions ranging with a small band of mares. This is especially so on the Indian reservations, where in several cases as high as 40 per cent of the band were stallions. Under such conditions a mare during the period of heat is served repeatedly. The vaginal mucous membrane becomes a livid red and slight abrasions are not uncommon. If examined shortly after the subsidence of the period of heat the vaginal mucosa will present a mottled variegated appearance, being red, dark red, and even purple in patches.

In the alkali districts during hot weather it is not uncommon to see horses with extensive chafing between the thighs, in the folds of skin on either side of the vulva, or on the loose folds of the sheath, as a result of the natural secretions mixed with alkali dust. Extensive depigmentation of the affected area is the result. Such depigmented areas and those resulting from abrasions or lacerations are irregular in outline and, unless from a deep laceration, are not permanent, whereas those due to dourine are usually circular in outline, cicatricial in character, and permanent. Natural depigmented areas are common in the so-called "Arabian" horses of the western range and in those animals with an admixture of the blood of the pinto pony, a species of equine albino very popular among the Indians.

Ulcers on the mucosa of the genitals may be mistaken for glanders, especially when the lymph vessels and lymph glands are simultaneously inflamed. In this case the further progress of the disease, serum diagnosis, mallein test, or inoculation experiments will furnish definite diagnostic information.

Dourine may also be mistaken for surra in countries where the latter disease prevails, but as surra does not exist in the United States, it need not be considered from a differential standpoint in this country.

Phlegmonous inflammation and pyemic abscesses, with swelling of the adjacent lymph glands, may sometimes occur after copulation in mares and stallions which are suffering from an ichorous purulent discharge, but the absence of further progress of the condition will easily decide the diagnosis.

Melanotic tumors appearing about the anus and vulva of gray horses and carcinoma of the penis have been the cause of several inspections for suspected dourine, but they should never be mistaken for lesions of dourine by anyone in the least familiar with this disease.

TREATMENT.

Little benefit can be obtained from the medicinal treatment of this chronic malady, nor is such treatment desirable in this country, where the disease has existed only in restricted areas and where sanitary considerations demand its prompt extirpation. Some cases, however, have been observed where improvement and recovery followed local treatment when applied in the early stages of the infection. When, however, any systemic symptoms appear, drugs seem to be useless and deaths follow after very varying periods of time in different cases.

As the infection takes place through the genital apparatus, the thorough application to these parts of antiseptic solutions with the idea of destroying the trypanosomes before they obtain access to the general circulation may be looked upon as the most rational treatment. This, although practicable in the male, is extremely difficult to accomplish thoroughly in the female. Toward this end corrosive sublimate, 1 to 2,000, or 2 per cent solution of carbolic acid or creolin, should be injected into the vagina of the mare and the sheath and penis of the stallion immediately upon the first appearance of inflammation of the genitals following the act of coition in infected localities, or where for any reason the presence of the disease is to be suspected.

After the systemic symptoms of urticarial eruption and paresis with rapid loss of flesh in spite of a good appetite begin to appear, the symptomatic treatment with stimulants and alteratives has been recommended, but is of very slight value except to prolong the life of the patient. Among such drugs may be mentioned strychnin (1 grain three times daily) or potassium iodid (2 to 5 drams daily) for their alterative action. Marchal, of the remount depot, Constantine, Algeria, reports on the treatment of six stallions with cacodylate of soda, 1 gram in 5 c. c. of distilled water, given in two doses daily subcutaneously for five consecutive days with seven days interval, while others have recommended atoxyl, and recently Meissner has been experimenting with arsenophenylglyzin. Although the statistics of these lines of treatment are very limited, they seem to give very promising results and at least deserve further trial in those foreign countries where the disease is indigenous.

During the course of treatment care should be taken not to excite the sexual ardor of the patient, as this under all circumstances augments the symptoms, and indeed the act of copulation, in the mare pecially, may revive the symptoms of the disease in the acute stage when to all external appearances the animal had recovered from a previous infection.

METHOD OF ERADICATION.

Sanitary measures looking to the eradication of dourine must depend on the principle that horses infected with dourine should be excluded from breeding. This action is well founded, for, in spite of the possibility of cure, there are as a matter of fact frequent relapses, and further, trypanosomes may exist for months in the sexual organs of the apparently cured animal. Therefore, it is very essential to destroy the diseased mares and to castrate the affected stallions. The objection to spaying mares is that if they should be sold and attempt to breed, the disease may be contracted by the serving stallion and thus spread. On the other hand, stallions which are castrated before the appearance of paralytic symptoms become sound and well, but the stallions even after castration will frequently serve mares. They should therefore be prevented from mingling with mares for a month after the ulcers are healed.

Dourine, being conveyed solely by coitus, is not a difficult disease to stamp out in a farming community such as in Illinois, where the first outbreak occurred, or in Iowa, where the infection appeared in 1903 and 1911. But when the disease reached the open range and infected horses which ran in the foothills and "bad lands" of Nebraska and South Dakota, respectively, the difficulties increased manyfold, as inspections in many cases could be made only at the spring round-up. Even then there were but frequently but 60 to 70 per cent of the horses gathered up, owing to the rough condition of the land and the impossibility of seeing the stray animals.

After mature consideration a definite policy was decided upon which consisted in the slaughter of diseased mares, castration or slaughter of diseased stallions, castration or quarantine of exposed stallions, and the frequent reinspection of exposed mares. It was further decided to keep a sufficient number of men in the infected districts to carry out this policy, and Dr. E. T. Davison was placed in charge of the work of eradication with headquarters at Rushville, Nebr. To his capable and energetic efforts must be largely credited the satisfactory results which have been accomplished.

With the view of preventing the shipment of diseased animals from the infected districts the Secretary of Agriculture issued an order under date of January 20, 1903, prohibiting the transportation or movement of any horses in the counties of Dawes, Boxbutte, Sheridan, and Cherry, in the State of Nebraska, and in the Pine Ridge and Rosebud Indian Reservations and the counties of Custer and Fall River, S. Dak., to any other State or Territory or the District of Columbia, unless first inspected by an inspector of this bureau and accompanied by a certificate issued by the said inspector.

On March 10, 1903, the Secretary of Agriculture, with the concurrence of the Secretary of the Interior, issued an order which was posted throughout the above-named Indian reservations prohibiting any stallion or stallions from running at large within the bounds of these reservations, also directing that any uncastrated male horse 1 year of age or older found running on the range or at large in these reservations be castrated, and that all stallions belonging to owners living on White Clay Creek, or within 1 mile thereof, should be either castrated or kept under close quarantine until further orders; also prohibiting, furthermore, the breeding of horses in herds in which diseased animals had been found, under any circumstances, whether in fenced pastures, inclosures, or otherwise; and directing, with a provision for appraisement and indemnity to owners, that any animal or animals showing symptoms of dourine or known to have been exposed to the disease should, in the discretion of an inspector or employee of the Department of Agriculture, be immediately quarantined, and maintained in quarantine at the expense of the owner or owners until released by the inspector or condemned and slaughtered. A statement was also included to the effect that any person, company, or corporation knowingly violating the provisions of this order would be guilty of a misdemeanor, and on conviction liable to a fine of not less than $100 nor more than $1,000, or to imprisonment not more than one year, or to both such fine and imprisonment.

As a result of the thoroughness of method followed in the prosecution of this work, all the diseased animals in Nebraska were soon detected and either destroyed or castrated. But cases continued to appear on the Pine Ridge Reservation with disconcerting frequency as a result of the many difficulties attendant upon range inspection. With a view of handling this work of eradication to better advantage, a number of veterinarians, including the writer of this paper, were sent to the Pine Ridge Indian Agency in June, 1903, for the purpose of making inspections at the time of the annual round-up. Inspection camps were established, one veterinarian and an experienced roper being assigned to each of the five districts on the reservation—Wakpamini, White Clay, Porcupine, Wounded Knee, and Medicine Root. All the animals were rounded up in each district, and all diseased mares as well as affected stallions, which were of the inexpensive broncho type, were purchased and killed, while the healthy stallions were castrated unless the owner agreed to keep the animal off the open range. In this case the stallion was tagged and kept quarantined on the premises. The five round-up parties gradually worked toward Pass Creek, where the final round-up took place. At this time all animals which estrayed from one district to the other during the year were returned and animals which strayed in from the adjacent sections of Nebraska and South Dakota were claimed by owners and removed by them after inspection. This arrangement made possible the inspection of practically all the horses running at large on those ranges. Thus the advantages to be gained were numerous, and large numbers of animals which habitually ran at large on the open range, a great majority of which had never been handled, were subjected almost at the same time to careful veterinary examination, as in the case of those usually kept in barns or inclosed pastures.

During the round-up season from June 1 to June 30, 1903, 9,455 horses were examined; 173 were slaughtered because of showing evidences of the disease, 6 of which were stallions and 167 mares. In addition, 1,270 stallions running at large, these being the most effective spreaders of the disease, were castrated, and 185 stallions to be used for breeding purposes were tagged for identification. During the year the total number of animals inspected was 16,287; number found diseased and slaughtered, 511; number quarantined as suspicious, 277; number of stallions castrated, 1,889. The average price paid by the department for animals slaughtered because of being diseased was $17.52. Castrations, having been performed by employees of the bureau, incurred no expense, and because of this operation the probability of the transmission of the disease through the animal operated on was removed. Some of the Indian owners objected strenuously to the castration of their pinto stallions, but as a rule very little opposition was met from them, although many regretted the prospects of only a few "papoose ponies" the following season. All stallions left for breeding purposes were tagged with a quarantine tag, kept under quarantine restrictions, and regularly inspected, so that should the disease develop at any point it could be promptly detected and stamped out. This same systematic policy was followed during the next few years in this section.

Notwithstanding the subsequent failure of any cases to appear, constant vigilance was kept over the horses in the infected sections to make sure that none of the contagion persisted. In order to make it an incentive to report any diseased animals which might have been hidden by owners, an order was issued by the Secretary of Agriculture on April 15, 1907, offering a reward of $50 for authentic information leading to the discovery of the ownership and location of a stallion or a jack affected with dourine, and the sum of $25 for similar information leading to the discovery of a female animal affected with the disease in the quarantined district, provided that when more than one diseased animal should be found belonging to the same owner, or on the same premises, only one reward should be paid. This reward was offered in addition to the usual compensation to the owner. Notwithstanding that this order has been in force since 1907, not one case of dourine has been found in that district, and consequently no reward has ever been claimed. Numerous suspected cases, however, have been reported from time to time since 1906 in different sections of the country by veterinarians and horsemen, but with the exception of the recent Iowa cases they have been shown on investigation to have been some other disease simulating dourine in some particulars, and usually proving to be coital exanthema.

Investigations have been made in various parts of South and North Dakota, Nebraska, the Indian reservations, Washington, Oregon, Wyoming, Oklahoma, Utah, and Montana. A careful inspection has also been made of the range horses in some of the principal range States, several thousand animals having been inspected in such States in the round-up work, with the assistance of veterinary inspectors engaged in other lines of field service, such inspections having been made for the detection of scabies, glanders, and dourine. The general method has been to have the horses in any section of the country that has ever been regarded with suspicion rounded up during the breeding season and examined. In the States of Montana and Wyoming the horses on the Indian reservations have likewise been examined, not because of disease having been reported among the Indians' horses in these States, but because of the fact that if there were any disease in the country the conditions prevailing on the Indian reservations would be likely to furnish an ideal medium for its development and dissemination. For many years the Crows, Arapahoes, Sioux, and Shoshones have journeyed back and forth in the fall of the year between the Sioux Reservation at Pine Ridge and the Wind River Reservation in central Wyoming and the Crow Reservation in southern Montana. It is their custom to leave some of their horses as gifts to their friends, and it was the possibility that some of these animals might have been affected with dourine that caused such careful inspections to be made at the neighboring Indian reservations. Representative herds of range horses have likewise been examined, even when such herds have never been regarded as suspicious, and all herds that were ever regarded with suspicion were kept under surveillance for several years.

In the eradication of a disease like dourine, especially when it is confined to a relatively small area, compensation for the affected animals destroyed has a very wholesome influence on the owner in inducing him to notify the proper authorities of the presence of suspected cases of the disease. In many instances the diseased animals are capable of doing some work, and unless they are bred there is no danger to other animals from them. It is this danger of being bred which makes it essential that they should be destroyed. The existence of this disease is a great menace to the horse industry, and speedy eradication wherever it is discovered is therefore very important.

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Issued February 15, 1912.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 143.
A. D. MELVIN, CHIEF OF BUREAU.

THE MAINTENANCE RATIONS OF FARM ANIMALS.

BY

HENRY PRENTISS ARMSBY, PH. D., LL. D.,
Director of the Institute of Animal Nutrition of The Pennsylvania State College; Expert in Animal Nutrition, Bureau of Animal Industry.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., August 12, 1911.

Sir: I have the honor to transmit herewith, and to recommend for publication in the bulletin series of this bureau, a manuscript entitled "The Maintenance Rations of Farm Animals," by Dr. Henry Prentiss Armsby, who has charge of the cooperative work in animal nutrition between this bureau and the Institute of Animal Nutrition of The Pennsylvania State College. The paper is based not only on Dr. Armsby's own work, but on that of other investigators as well, and is believed to cover the subject thoroughly.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE MAINTENANCE RATIONS OF FARM ANIMALS.

INTRODUCTION.

Feed is supplied to farm animals in order that they may either yield products useful to man as materials for human food and clothing or serve him by the performance of mechanical work. But as a factory must first be supplied with enough power to keep in motion the shafting, belting, and other machinery before any product can be turned out, so the animal mechanism must be provided with sufficient feed to maintain the processes essential to life before any continued production is possible. The amount of feed required for this purpose is called the maintenance ration of the particular animal. It is the quantity of feed necessary simply to support the animal when doing no work and yielding no material product. If an animal receiving exactly a maintenance ration were subjected to a so-called balance experiment, there would be found an exact equality between income and outgo of ash, nitrogen, carbon, hydrogen, and energy, showing that the body was neither gaining nor losing protein, fat, carbohydrates, or ash.

The word "maintenance" is sometimes used popularly in another sense to signify the total amount of feed required, for example, by a horse in order to perform his daily work or by a calf in order to make a normal growth. It is important to grasp the idea that, in its technical sense, the maintenance requirement means the minimum required simply to sustain life. The feed of the horse or calf would, from this point of view, be regarded as consisting of two portions; one of these is the maintenance ration, which if fed by itself would just support the horse at rest or the calf without growth, and the other the productive portion of the ration by means of which work is done or growth made. To recur to the illustration of the factory, the maintenance ration keeps the empty machinery running, while the additional feed furnishes the power necessary to turn out the product.

It might seem at first thought that not much importance attaches to a study of the maintenance ration. The animal kept on such a ration yields no direct economic return and hence simple maintenance feeding should be avoided, so far as practicable, and when it appears desirable to practice it the observation of the skilled stockman, especially if supplemented by occasional weighings, will usually suffice to determine whether or not the end is being attained. Nevertheless, the subject has significance for practice as well as for science. A very considerable fraction of the feed actually consumed by farm animals—on the average probably fully one-half—is applied simply to maintenance. But if half of the farmer's feed bill is expended for maintenance, it is clearly important for him to know something of the laws of maintenance—how its requirements vary as between different animals, how they are affected by the conditions under which animals are kept, how different feeding stuffs compare in value, etc.—as well as to understand the principles governing the production of meat, milk, or work from the other half of his feed.

Physiologically, too, the maintenance requirement represents the demand of the basal life processes. The prime necessity of the organism is to maintain itself. It must live before it can grow or propagate its kind, and in the phenomena of maintenance the fundamental processes of nutrition may be studied uncomplicated by the demands of growth, fattening, or reproduction.

THE FASTING KATABOLISM.[1]

Unlike the operations of a factory, which cease when the power is shut off, the activities of the animal do not stop when food is withdrawn, but continue for a variable length of time at the expense of the materials of the body. It is as if the materials of the factory itself were being cut up and used for fuel under the boilers. Men have fasted voluntarily for 30 days or more without obvious permanent ill effects, and there are records of dogs having survived fasting periods of from 90 to 100 or more days. In the fasting animal at rest the vital activities are reduced, as it were, to their simplest terms, practically only those functions being active which are essential to continued life. The following approximate estimate by Zuntz of the factors of the katabolism of a fasting man may serve to give a general idea of their nature and relative importance. The figures show the oxygen consumption per minute of the various tissues and its percentage distribution:

---

[1] For references to the literature of the fasting katabolism compare:

Magnus Levy. Von Noorden's Pathologie des Stoffwechsels, 2d ed., I, 222–225 and 310–315.

Tigerstedt. Nagel's Handbuch der Physiologie des Menschen, I, 375–391.

Lusk. The Science of Nutrition. 2d ed., 54–85.

Benedict. Metabolism in Inanition. Carnegie Institution of Washington, Publication No. 77, II, 361–364.

Armsby. Principles of Animal Nutrition, 3d ed., 80–92 and 340–347.

Consumption of oxygen in fasting man weighing 70 kilograms—Zuntz.

	Cubic centimeters per minute.		Percentage.	
Circulation and respiration		30.0		12.45
Voluntary muscles		112.0		46.49
Glands and other organs:				
Liver	45.0		18.68	
Small intestine	25.1		10.42	
Kidneys	10.5		4.36	
Pancreas	9.3		3.86	
Large intestine	7.0		2.91	
Salivary glands	2.0		.83	
	—	98.9	—	41.06
Total		240.9		100.00

According to the foregoing table nearly 60 per cent of the metabolism of a fasting man is due to the work of the muscles, including that of respiration and circulation as well as the limited activity of the voluntary muscles, while somewhat over 40 per cent is due to the internal organs. No equally complete data are available for farm animals, but the supposition seems justified that their metabolism in its main features is not greatly unlike that of man. It may be noted that Zuntz and Hagemann found the energy expended in respiration and circulation by the horse in a state of rest to be, respectively, 4.7 and 5.01 per cent of the total metabolism. The sum of these—9.71 per cent—is approximately comparable with the corresponding figure for man.

PURPOSE OF THE FASTING KATABOLISM.

The animal body is primarily a transformer of energy. From the biochemical standpoint the essential phenomenon of physical life is the transformation of chemical into kinetic energy which accompanies the breaking down of more or less complex molecules into simpler ones, and all vital activities are essentially manifestations of energy. In the fasting state this energy is derived from the store of chemical energy contained in the materials of the body itself. The very act of living, in the foregoing view of it, is synonymous with the expenditure by the organism of its stored-up capital of energy. The prime and dominating purpose of the fasting katabolism, therefore, is to supply energy for the life actions.

But since the necessary activities of the fasting organism are carried on by means of energy derived from the katabolism of materials contained in the tissues, the body's store of matter and of energy is being constantly depleted. To prevent or replace this loss will require a corresponding supply of available material and energy in the feed. A knowledge of the kind and quantity of material katabolized during fasting and of the amount of energy liberated, therefore, is obviously the first step toward ascertaining the supply necessary in the feed.

THE MATERIAL KATABOLIZED.

Ash.—The fasting organism suffers a continual loss of the so-called ash ingredients of its tissues, including both the sulphur and phosphorus of its proteins and the more distinctly "mineral" elements, such as sodium, potassium, calcium, magnesium, chlorin, etc. These elements are just as essential to the existence of the animal as are the carbon, nitrogen, hydrogen, and oxygen of the so-called "organic" compounds.

The study of this branch of the subject, however, has hardly progressed far enough as yet to permit a definite formulation of the ash requirements of domestic animals. The present paper, therefore, will be confined to a discussion of the maintenance requirements in the more limited and customary sense, including only those substances whose function it is wholly or in part to serve as sources of energy.

Fat.—It is a familiar conception that fat formation is the body's method of disposing of surplus feed, and that the body fat is a store of reserve fuel material. The converse of this fact is equally familiar. The fasting or insufficiently fed animal loses fat and may reach a stage of extreme emaciation before the active tissues fail to perform their duties. Obviously, the fasting animal lives very largely upon its reserve fat. These conclusions from common observation have been fully confirmed by comparative analyses of the carcasses of well-fed and of fasted animals as well as by the results of balance experiments in which the exact nature of the outgo from the body has been determined.

Carbohydrates.—In addition to fat, the body stores up more or less nonnitrogenous matter in the form of glycogen in the liver and muscles. During the first few days of fasting this store of carbohydrates is also drawn upon, as is indicated by the fact that the respiratory quotient tends to approach unity, while later the amount katabolized becomes very small. This is well illustrated by Benedict's[1] experiments upon fasting men. The average results of a number of experiments in which men fasted for from two to seven consecutive days were as follows:

Glycogen katabolized by fasting men—Benedict.

Day.	Number of subjects.	Glycogen katabolized.	
		Total.	Per kilogram of body weight.
		Grams.	*Grams.*
First day	14	110.0	1.69
Second day	[2] 13	40.3	.62
Third day	6	21.8	.36
Fourth day	5	23.3	.40
Fifth day	[2] 1	8.2	.14
Sixth day	1	21.7	.38
Seventh day	1	18.7	.33

---

[1] The Influence of Inanition on Metabolism. Carnegie Institution of Washington, D. C., 1907, p. 464.

[2] Another subject showed a slight gain of glycogen.

Protein.—Balance experiments, however, while confirming the conclusion that the loss of tissue in fasting usually consists chiefly of fat together with some carbohydrates, show that there is also a continual breaking down of body protein and a corresponding excretion of urinary nitrogen. While the energy supply of the fasting animal is chiefly derived from the breaking down of nonnitrogenous material, the functional activity of the tissues necessarily involves the katabolism of a certain amount of protein.

RATIO OF PROTEIN TO TOTAL KATABOLISM.

Qualitatively, then, the katabolism of the fasting animal is substantially a katabolism of fat and of protein, and it becomes of interest to consider the quantitative relations between the two. Such a comparison is best made on the basis of the amounts of energy liberated in the body in the katabolism of protein and of fat respectively. This aspect of the subject has been treated especially in an article by E. Voit[2] in which the results of a considerable number of fasting experiments are compiled and discussed. While some of Voit's computations are based on estimates, they are sufficiently accurate to outline definitely the main features of the fasting katabolism. Including only experiments on animals well nourished at the beginning, he obtained the following averages for the percentage of the total energy liberated which was supplied by the katabolism of protein in the case of a number of different species. The results of the first day or two of fasting are not included in the averages.

Proportion of energy derived from protein in fasting—E. Voit.

Kind of animal.	Live weight.	Protein katabolism in per cent of total katabolism.
	Kilos.	*Per cent.*
Swine	115.0	7.3
Man	68.7	15.6
Dog	28.6	13.2
	18.7	10.7
	7.2	13.5
Rabbit	2.7	16.5
Guinea pig	.6	10.8
Goose	3.3	7.4
Hen	2.1	10.0

While both the total and protein katabolism naturally showed a wide range as to absolute amount, whether per head or per unit of live weight, the ratio of protein to total katabolism proved notably uniform with only two exceptions. The experiments upon dogs, 27 in number, included in the foregoing table furnished the basis for the following comparison, showing that in 74 per cent of the cases the ratio ranged from 10 to 17 per cent.

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[1] Zeitschrift für Biologie, vol. 41, p. 167.

Protein katabolism of dog in per cent of total katabolism.

	Number of cases.	
	Absolute.	Per cent.
Less than 10 per cent	4	14.8
10 to 14 per cent	15	55.6
14 to 17 per cent	5	18.5
More than 17 per cent	3	11.1
	27	100.0

It may be accepted as established, then, that in what may be spoken of as the normal fasting animal, in which the influence of the previous feeding has disappeared and in which, on the other hand, the fat reserve has not been exhausted, the protein katabolism constitutes a fairly small percentage of the total katabolism, both being expressed in terms of energy.

INFLUENCE OF BODY FAT.

It is clear, however, from the foregoing figures that the ratio of protein to total katabolism may vary considerably. The most important factor in this variation has been found to be the relative amount of fat contained in the body. So long as fuel material in the form of body fat is readily available, the amount of protein katabolized remains small. Usually, however, the store of fat in the body is less than that of protein, while in fasting its exhaustion is relatively more rapid. There comes a time, therefore, when the supply of non-nitrogenous material to the tissues begins to flag. When this happens, the protein katabolism begins to increase—that is, when the supply of reserve fuel material runs low the organism begins to use the protein of its own tissues as a source of energy, and E. Voit[1] shows that this occurs whenever the ratio of fat to protein remaining in the body falls below a certain limit. If the animal was originally well fed, this rise in the protein katabolism occurs only shortly before death, from which fact it has received the name of the premortal rise. In the case of very fat animals this point may never be reached, while, on the other hand, in a lean animal the protein katabolism may increase steadily from the very beginning of the fasting. The following three experiments upon a fat guinea pig, a moderately fat dog, and a lean rabbit, cited by Voit from Rubner's experiments, may serve to illustrate these three types of fasting katabolism:

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[1] Loc. cit., p. 502.

Proportion of energy derived from protein—Rubner.

Guinea pig.		Dog.		Rabbit.	
Day of fasting.	Protein katabolism in per cent of total katabolism.	Day of fasting.	Protein katabolism in per cent of total katabolism.	Day of fasting.	Protein katabolism in per cent of total katabolism.
	Per cent.		*Per cent.*		*Per cent.*
2	10.4	2–4	16.3	3	16.5
3	11.1	10–11	13.1	5–7	23.6
4	11.0	12	15.5	9–12	26.5
5	11.9	13	17.4	13–15	29.8
6	11.8	14	20.0	16	50.1
7	6.9			17–18	96.4
8	11.2				
9	10.9				

INFLUENCE OF SURPLUS PROTEIN.

On the other hand, as Pettenkofer and Voit long ago showed,[1] when an animal which has been previously receiving large amounts of protein is deprived of feed, the high protein katabolism which is observed during the first two or three days of fasting is accompanied by a relatively smaller katabolism of fat. Thus in an experiment with a dog, cited on a subsequent page (p. 74) to illustrate the initial fall of protein katabolism, respiration experiments were made on the second, fifth, and eighth days, with the following results:

Katabolism of fasting dog—Voit.

Day.	Urinary nitrogen.	Fat katabolized.	Protein katabolized in per cent of total katabolism.
	Grams.	*Grams.*	
Second day	11.6	86	26.2
Fifth day	5.7	103	12.7
Eighth day	4.7	99	11.1

Obviously we have here the reverse of what takes place in the later days of fasting, viz, a gradual substitution of fat for protein as the readily available supply of the latter in the body is reduced. Doubtless the effect would have been found to be still more marked on the first day of the fasting, when the protein katabolism was equivalent to 28.1 grams of nitrogen.

RELATIVE CONSTANCY OF ENERGY KATABOLISM.

The results which have just been considered regarding the nature of the material katabolized in fasting and the way in which fat, carbohydrates, and protein mutually replace each other as fuel material as one or the other is most available fully substantiate the assertion made on page 9 that the controlling factor in the katabolism of the fasting body is the demand for energy. As there stated, the body is essentially a converter of energy, and protein occupies a peculiar position in nutrition simply so far as it is a part of the necessary mechanism for this conversion. These facts can hardly have failed to suggest that the demand for energy must be relatively constant in the same individual, and that such is in fact the case has been demonstrated by a large number of experiments.

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[1] Zeitschrift für Biologie, vol. 7, p. 369.

For example, in the experiment by Voit upon a dog, just cited, the energy of the protein and fat katabolized on the three days, as computed from the data for the urinary nitrogen and for the fat katabolism, was as shown in the following table, from which it appears that the total energy katabolized, especially when computed per kilogram of live weight, was approximately the same on the different days.

Constancy of katabolism of fasting dog—Voit.

Day.	Live weight.	Energy from protein.	Energy from fat.	Total energy.	Total energy per kilogram live weight.
	Kilos.	*Calories.*[1]	*Calories.*[1]	*Calories.*[1]	*Calories.*[1]
Second day	32.87	289.3	816.9	1,106.2	33.66
Fifth day	31.67	142.2	978.5	1,120.7	35.38
Eighth day	30.54	117.2	942.4	1,059.6	34.70

[1] Throughout this bulletin the word "calorie" signifies the large, or kilogram, calorie, unless the contrary is specifically stated.

The same constancy is illustrated by Rubner's experiments on a rabbit, a dog, and a guinea pig, whose relative protein katabolism was tabulated on page 13. The latter is repeated in the following table, together with the heat production as measured directly or the carbon dioxid excreted, which may be assumed to be an approximate measure of the energy katabolized. As the table shows, notwithstanding very considerable variations in the relative amount of protein katabolized, the total energy liberated in the body was relatively very constant.

Constancy of katabolism of fasting animals—Rubner.

Day of fasting.	Guinea pig.		Dog.		Rabbit.	
	Protein katabolism in per cent of total katabolism.	Heat production per kilogram.	Protein katabolism in per cent of total katabolism.	Carbon dioxid per kilogram.	Protein katabolism in per cent of total katabolism.	Carbon dioxid per kilogram.
		Calories.		*Grams.*		*Grams.*
First	....	149.9	....	20.70	....	....
Second	10.4	162.6	....	17.83	....	....
Third	11.1	156.5	16.3	....	16.5	....
Fourth	11.0	140.5	....	17.99	....	....
Fifth	11.9	137.3	....	....	23.6	17.26
Sixth	11.8	150.6	....	....		....
Seventh	6.9	157.4	....	....		15.90
Eighth	11.2	155.6	....	....	....	....
Ninth	10.9	162.6	....	....	26.5	15.90
Tenth	....	....	13.1	18.70		15.65
Eleventh	....	....		17.86		....
Twelfth	....	....	15.5	16.13		17.18
Thirteenth	....	....	17.4	17.06	29.8	15.81
Fourteenth	....	....	20.0	16.12		15.95
Fifteenth	....	....	....	....		15.90
Sixteenth	....	....	....	....	50.1	....
Seventeenth	....	....	....	....	96.4	....
Eighteenth	....	....	....	....		....

Benedict[1] has obtained like results for the heat production of man as measured directly by means of the respiration calorimeter. For example, in an experiment[2] covering seven days the following quantities of energy were katabolized daily.

Constancy of katabolism of fasting man—Benedict.

Day of fasting.	Energy from protein.	Energy from fat.	Energy from glycogen.	Total energy.	Energy per kilogram body weight.	Protein katabolism in per cent of total katabolism.
	Calories.	*Calories.*	*Calories.*	*Calories.*	*Calories.*	*Per cent.*
First day	318	1,175	272	1,765	29.7	17.7
Second day	286	1,385	97	1,768	29.9	16.0
Third day	303	1,471	23	1,797	30.8	17.0
Fourth day	248	1,422	105	1,775	30.8	14.3
Fifth day	221	1,394	34	1,649	29.0	13.5
Sixth day	218	1,244	91	1,553	27.5	14.1
Seventh day	204	1.286	78	1,568	28.0	13.2

This constancy of the fasting katabolism evidently is in accord with the conception of it outlined on page 9 as the measure of the energy necessary to carry on the vital activities of the body. The functions of circulation, respiration, excretion, etc., must go on continually in a state of so-called rest, the muscular tonus must be maintained and divers minor muscular movements executed. In the aggregate all these result in the expenditure of a relatively uniform amount of energy from day to day. This energy in the fasting animal is supplied mainly by the katabolism of protein and fat. In the intermediate stages of fasting, as has been shown, the katabolism is largely that of fat, but the ratio between fat and protein katabolized may differ widely according to circumstances. In other words the protein requirement, or at least the amount of protein used, may vary, while the energy requirement remains nearly constant. The fasting organism requires a definite quantity of energy, but seems more or less indifferent as to its source.

---

[1] The Influence of Inanition on Metabolism. Carnegie Institution of Washington, 1907, Publication No. 77.

[2] Experiment No. 75 on S. A. B., pp. 188, 483, and 496.

THE ENERGY REQUIREMENT FOR MAINTENANCE.

In the fasting animal the store of potential energy in the body is diminished daily by the amount required to carry on the vital activities, this amount being, as just shown, relatively constant. In order to prevent such a loss and maintain the store of body energy, it is evident that a corresponding quantity of energy must be supplied in the feed and that a maintenance ration is one which supplies this requisite quantity.

REPLACEMENT OF NUTRIENTS.

For this purpose experiments have shown that the various digestible nutrients may replace each other or the ingredients of the body through a very wide range.

FEED FAT AND BODY FAT.

Fat fed to a previously fasting animal diminishes or suspends the loss of body fat. The following averages of Pettenkofer and Voit's experiments,[1] computed from Atwater and Langworthy's digest,[2] may serve to illustrate this substitution of feed fat for body fat:

Replacement of body fat by feed fat—Pettenkofer and Voit.

Food.	Number of experiments.	Gain or loss by body.	
		Nitrogen.	Fat.
		Grams.	*Grams.*
None	5	−6.64	− 97.76
100 grams fat	2	−4.90	− 16.25
350 grams fat	1	−7.70	+113.60

The smaller amount of fat not only diminished the protein katabolism but also largely reduced the loss of fat from the body. While the larger amount of fat showed a tendency to increase the protein katabolism, it not only suspended the loss of body fat but caused a storage of fat in the organism. Of course there is no means of distinguishing in such a case between feed fat and body fat, but it is most natural to suppose that the resorbed fat of the feed, being already in circulation in the body, is more easily accessible to the active cells than the stored-up fat of the adipose tissue and is therefore metabolized in preference to the latter.

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[1] Zeitschrift für Biologie, vol. 5, p. 370.

[2] U. S. Department of Agriculture, Office of Experiment Stations, Bulletin 45.

CARBOHYDRATES AND BODY FAT.

Experiments precisely similar to those on fat just described show that carbohydrates may also diminish or suspend the loss of body fat. This may be illustrated by the results of three experiments upon a dog by Rubner.

Replacement of body fat by carbohydrates—Rubner.

Food.	Total nitrogen of excreta.	Total carbon of excreta.	Gain or loss of fat.
	Grams.	*Grams.*	*Grams.*
None	1.94	38.18	−40.99
76.12 grams cane sugar	1.45	43.19	− 8.41
104.97 grams cane sugar	1.07	47.78	+ .51
None	1.42	26.47	−28.10
42.96 grams starch	1.53	33.28	−10.54
None	2.00	31.53	−32.10
57.38 grams starch	1.52	39.67	−10.74

CARBOHYDRATES AND FEED FAT.

Rubner substituted dextrose for fat in the diet of a dog receiving also a fixed amount of lean meat. The results of this substitution are given in the following table, and show that with the larger amount of dextrose in place of the fat previously fed the loss of body fat was prevented:

Replacement of feed fat by carbohydrates—Rubner.

Ration.	Feed per day.			Gain or loss by animal.	
	Meat.	Fat.	Dextrose.	Nitrogen.	Carbon.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Meat and fat	300	42	....	+1.81	+1.27
Do	300	50	....	+ .10	+9.31
Meat and dextrose	300	....	63.7	+1.78	−7.44
Do	300	....	79.7	+2.28	−8.15
Do	300	....	115.5	+1.98	+6.21

FEED PROTEIN AND BODY FAT.

It has already been shown that body protein may replace body fat in the katabolism of the fasting animal. A similar substitution of feed protein for body fat may take place. When protein is given to a previously fasting animal it is a well-known fact that the nitrogen of the protein is rapidly split off and excreted, while the nonnitrogenous portion of the molecule serves as a source of energy to the organism. (Compare pp. 78 to 82.) This nonnitrogenous residue can be substituted for body fat, as is illustrated in an experiment by Rubner in which extracted lean meat was given to a fasting animal, with the result tabulated below:

Replacement of body fat by protein—Rubner.

	Nitrogen of food.	Nitrogen katabolized.	Fat katabolized.
	Grams.	*Grams.*	*Grams.*
Fasting	0	5.25	84.39
Fed	35.22	26.37	28.37
Difference	....	+21.12	−56.02

FAT OR CARBOHYDRATES AND PROTEIN.

A certain minimum of protein is essential to the maintenance of the protein tissues of the body, but feed protein in excess of this amount undergoes rapid katabolism and serves substantially as a source of energy. Such an excess of protein in the feed can be replaced by nonnitrogenous nutrients, particularly the carbohydrates. This effect of fat or carbohydrates as a substitute for protein may be illustrated by the following tabulation of the average results of a number of Pettenkofer and Voit's experiments:

Replacement of feed protein by fat or carbohydrates—Pettenkofer and Voit.

Rations.	Feed per day.				Gain or loss by body.	
	Meat.	Fat.	Starch.	Grape sugar.	Nitrogen.	Carbon.
Protein only:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Series I	1,500	....	....	....	0	+ 3.3
Average of all (22 experiments)	1,500	....	....	....	+0.6	+ 8.7
Protein and fat:						
100 grams fat (1 experiment)	500	100	....	....	+ .3	+27.1
200 grams fat (5 experiments)	500	200	....	....	− .6	+67.3
Protein and carbohydrates:						
Starch (8 experiments)	500	5.3	200	....	−1.8	+ 9.0
Grape sugar (3 experiments)	500	....	....	200	−1.3	+ 7.2

It appears, then, that all the principal nutrients may serve to supply energy to the body, and the facts just considered show a remarkable degree of flexibility on the part of the animal organism as regards the nature of the material which can be utilized for its metabolism. Aside from the small minimum of protein required, the metabolic activities of the body may be supported now at the expense of the stored body fat, now by the body protein, and again by the protein, the fats, or the carbohydrates of the feed. Whatever may be true economically, physiologically the welfare of the mature animal is not conditioned upon any fixed relation between the classes of nutrients in its feed supply apart from the minimum requirement for protein.

AVAILABILITY OF ENERGY.

Since the chief function of the feed, aside from a minimum of protein, is to supply energy, it would be natural to suppose that the quantity of energy liberated in the body by the oxidation of any given substance (i. e., its metabolizable energy) would be the measure of its nutritive value. If one gram of starch, for example, can liberate 4.2 calories of energy in the body and a gram of fat 9.5 calories, apparently the relative values of the two should be in proportion to these figures. But while the metabolizable energy of the feed represents the maximum amount of energy which can be extracted from it by the organism, it does not follow that all of it can be utilized for maintenance. Energy is not something which can be fed into the organism regardless of its source, like fuel under a boiler. Whatever energy is in essence, so far as the animal is concerned it is carried as chemical energy by the compounds of the feed, and these must be such as can take part in the actual chemical changes occurring in the cells if their energy is to be utilized. The body can not, like a heat engine, avail itself of energy in the kinetic form. It is quite conceivable that a compound might be resorbed from the digestive tract and then simply oxidized to get rid of it without its entering into the cell metabolism. Its energy would be metabolized, that is, converted into the kinetic form, but it would be simply a source of heat and not of other forms of energy. Somewhat similar is the case of the chemical changes occurring in the digestive tract. Some of these, notably the fermentations of the feed, set free energy as heat, yet this energy plays no part in the actual metabolism of the tissues. It is clear, then, that we are not warranted in concluding that because, for example, a fasting animal breaks down body substance equivalent to 10 therms per day, therefore a ration containing 10 therms of metabolizable energy will suffice to maintain the animal. That will depend upon how completely the body is able to use the 10 therms of metabolizable energy supplied to it. In other words, the energy must not only be present, but it must be available energy.

If the metabolizable energy were all available to protect body tissue from oxidation, then giving feed to a fasting or partially fasting animal would be practically the substitution of one kind of fuel for another, and the total heat production would remain the same. It is, however, an observation as old as the time of Lavoisier that the consumption of feed tends to increase the heat production of an animal. That investigator observed the oxygen consumption of man to increase materially (about 37 per cent) after a meal, and subsequent experiments by a large number of investigators have fully confirmed these earlier results, so that the fact of an increased metabolism consequent upon the ingestion of feed is undisputed. It is especially to the investigations of Zuntz and his associates that we owe the unquestionable demonstration of this fact and of its significance in relation to the nutritive values of feeding stuffs.

These relations may perhaps be more clearly apprehended through an illustration taken from actual experimental work.

AVAILABILITY FOR CATTLE.

In an experiment by Armsby and Fries[1] a steer averaging 373.7 kilograms live weight was fed daily 3.2 kilograms of timothy hay, an amount known to be insufficient for maintenance. The potential energy contained in the feed, the losses in the various excreta, and the metabolizable energy of the ration were determined, with the following results:

Per day and head.

	Therms.	Therms.
Feed:		
3.199 kilos timothy hay		12.618
Excreta:		
4.786 kilos feces	5.247	
3.943 kilos urine	.627	
0.079 kilo methane	1.057	
Total		6.931
Metabolizable energy of ration		5.687

A balance experiment with the respiration calorimeter showed, as was expected, that the steer was living in part at the expense of his own tissues, the total loss of protein and fat being equivalent to 2.377 therms[2] per day.

In the period immediately following this one the same steer ate per day 5.194 kilograms of the same timothy hay, all the other conditions of the experiment being as nearly identical as possible. The metabolizable energy of this larger ration, determined in the manner just indicated, was 9.262 therms,[3] while a balance experiment showed that the loss of protein and fat had been reduced to the equivalent of 0.357 therm.[3]

The following comparison of the two periods can therefore be made:

Available energy of timothy hay.

	Ration.	Metabolizable energy of ration.	Energy of fat and protein lost by animal.
	Kilos.	*Therms.*	*Therms.*
Timothy hay	5.294	9.262	0.357
Do	3.199	5.687	2.377
Difference	2.095	3.575	2.020

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[1] Bureau of Animal Industry, Bulletin 128, pp. 177 and 184.

[2] Computed to 12 hours' standing.

[3] Corrected to the same live weight as in Period III.

On the lighter ration, the steer supplemented the energy derived from its feed by 2.377 therms derived from the katabolism of its own fat and protein, but when 2.1 kilograms of timothy hay was added to the ration, the amount of energy which had to be furnished by the body tissues was reduced to 0.357 therm. In other words, 2.1 kilograms of timothy hay supplied 2.020 therms of energy which was available to support the necessary bodily activities and which, therefore, could replace an equal amount which would otherwise have been derived from the katabolism of body substance. This was the contribution which this amount of hay made to the maintenance of the steer.

But the 2.1 kilograms of timothy hay added to the ration supplied, as the table shows, 3.575 therms of metabolizable energy. Clearly, then, a unit of metabolizable energy supplied by the digestible matter of the hay was less efficient than the same amount supplied by body substance. Only 56.5 per cent of it could be substituted for that previously supplied by the katabolism of the fat and protein of the body of the steer, while the remaining 1.555 therms, or 43.5 per cent, simply increased the heat production of the animal, the latter being as follows:

Daily heat production.[1]

	Therms.
On the heavier ration	9.619
On the lighter ration	8.064
	1.555

It is customary in such a case to speak of the 2.020 therms as the available energy of the hay added to the basal ration of Period III and to say that 56.5 per cent of the metabolizable energy of the hay was available. Such a method of statement does not necessarily imply that the remaining 43.5 per cent served no useful function in the body, but simply asserts that the net result to the organism was the same as if 56.5 per cent of the metabolizable energy were substituted unit for unit for energy derived from the katabolism of body substance and as if the remaining 43.5 per cent were useless. What the experiment really shows is that a unit of metabolizable energy in the hay had only 56.5 per cent of the value for maintenance of a unit of metabolizable energy in the body substance (chiefly fat) previously katabolized, but the first method of expression is both common and convenient and may be retained.

Experiments by the same authors on several other feeding stuffs have given results of the same general character as those just quoted. Of the metabolizable energy of these feeding stuffs, as directly determined in each experiment, the following percentages were found to be available in the above sense, while the remainder simply served to increase the heat production:

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[1] Corrected to 12 hours standing.

Average availability of metabolizable energy.

	Per cent.
Timothy hay, 5 experiments	56.32
Clover hay, 2 experiments	58.47
Corn meal, 1 experiment	69.12
Wheat bran, 2 experiments	55.36
Mixed grain (1 part wheat bran, 3 parts corn meal, 3 parts linseed meal O. P.), 4 experiments	57.42

Kellner's[1] extensive investigations upon the metabolism of fattening cattle have likewise demonstrated that in the productive feeding of these animals only part of the metabolizable energy supplied in excess of the maintenance ration is recovered in the gain produced, the remainder being converted into heat, so that the heat production increases with the amount of feed consumed.

AVAILABILITY FOR THE HORSE—ZUNTZ AND HAGEMANN'S RESULTS.

The foregoing results upon cattle have been cited because they illustrate simply and clearly the basic conception of the availability of feed energy and also because they are, so far as the writer is aware, the first experiments upon farm animals on submaintenance rations in which the complete balance of matter and of energy for 24 hours has been determined. Zuntz and Hagemann[2], however, had shown several years before in an extensive investigation that the increased metabolism which Zuntz and his associates had observed in dogs and men as resulting from the ingestion of food was even more marked in the case of the horse.

In their investigations the respiratory exchange of the animal was determined by the Zuntz method in short periods at various intervals after the consumption of more or less diverse rations, a small correction being added for cutaneous and intestinal respiration. By combining these results with those of a number of separate digestion trials in which the nitrogen and carbon of the feed and of the visible excreta were determined, an approximate determination of the total energy metabolism of the animal was also possible.[3]

For example, on the average of a number of experiments in which the metabolism shortly before feeding in the morning, shortly after feeding, and some hours later was determined by the methods just outlined, the following results, computed per kilogram per minute were obtained.[4]

	Oxygen consumed.	Energy liberated.
	c. c.	*Gram-calories.*
Fasting	3.339	16.929
36 minutes after feeding	3.648	18.510
3½ hours after feeding	3.704	18.787

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[1] Die Landwirtschaftlichen Versuchs-Stationen, Band 53, and Ernährung der Landwirtshaftlichen Nutztiere.

[2] Landwirtschaftliche Jahrbücher, vol. 27, Ergänzungsband III.

[3] For a more complete account of the method, compare Armsby, Principles of Animal Nutrition, pp. 386–387.

[4] Loc. cit., p. 282.

It was also found that coarse fodder (hay) produced a much more marked effect than did grain. The following comparison of the average of the experiments of period *c* on an exclusive hay diet with that of the experiments of period *f* on a mixed ration illustrates this fact.[1]

	Period *c*.	Period *f*.
Time since last fed ... hours	2.6	2.8
Ration:		
Hay ... kilos	About 10.5	4.75
Oats ... do
....	6.00
Straw ... do	....	1.00
Total digested nutrients (fat × 2.4) ... grams	4,125	5,697
Per kilogram and minute:		
Oxygen consumed ... cubic centimeters	3.9837	3.6986
Carbon dioxid given off ... do	3.6586	3.6695
Energy set free (computed) ... gram-calories	19.552	18.339
Energy katabolism per day and head ... calories	12,450	11,678

DIGESTIVE WORK FOR CRUDE FIBER.

Zuntz and Hagemann estimate the fuel value of the total digestible nutrients in the feed of the horse (including digestible crude fiber and digestible fat × 2.4) at 3.96 calories per gram, and on the basis of experiments on man made by Magnus-Levy in Zuntz's laboratory they assume that 9 per cent of the metabolizable energy of the digestible nutrients as thus computed is expended in their digestion. The hay ration of the foregoing table contained 1,572 grams less of (estimated) digestible nutrients than the mixed ration. The corresponding expenditure of energy in the digestion of these nutrients (9 per cent of their metabolizable energy) equals 580 calories. Accordingly the energy katabolism should have been 580 calories less in period *c* than in period *f*. It was actually 772 calories greater, a difference of 1,352 calories. This difference is ascribed to the presence in the hay ration of 648 grams more of total crude fiber and corresponds to 2.086 calories per gram of the latter.

WORK OF MASTICATION.

The foregoing computations relate to the expenditure of energy in the digestion of the food after it has entered the stomach. The same authors have also determined the increase in the gaseous exchange caused by mastication, deglutition, etc. For this purpose they compare[2] the excretion of carbon dioxid and the consumption of oxygen during the time actually occupied in eating with the corresponding amounts during rest, as shown by the average of a number of experiments made under identical conditions. On the assumption that the protein metabolism is unaltered, the amounts of carbohydrates and fat metabolized and the corresponding amounts of energy are calculated. The following is a summary of the results computed per kilogram of feed:

Energy expended in mastication of 1 kilogram—Zuntz and Hagemann.

Feed.	Number of experiments.	Oxygen consumed.	CO_2 excreted.	Equivalent energy.
		Liters.	*Liters.*	*Calories.*
Oats and cut straw (6:1)	8	12.964	10.679	64.17
Hay	8	33.840	27.813	167.44
Hay, oats, and cut straw	8	20.072	17.677	100.79
Maize and cut straw (6:1)	2	7.133	6.205	35.72
Green alfalfa	7	6.171	4.980	30.42
Computed for oats alone	....	....	....	47.00
Computed for maize alone	....	....	....	13.80

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[1] Loc. cit., pp. 276–279.

[2] Loc. cit., p. 271.

As was to have been expected, the work of mastication proves to be much greater in the case of hay than in that of grain. Maize gave a remarkably low result, while the lowest was obtained with green fodder. Even when the results on the latter are computed per kilogram of dry matter, they are still about 40 per cent lower than those on hay. A few experiments on old horses with defective teeth gave somewhat higher results for the mixture of oats and cut straw.

While pointing out that, as the above results show, other factors than the amount of crude fiber influence the work of mastication, they nevertheless believe that a sufficiently close approximation for practical purposes may be reached by computing the work of mastication upon the amount of crude fiber present, which gives an average of 0.565 calorie per gram, and using this factor to compute the work of mastication of the average ration. Adding this factor to the 2.086 calories computed for the work of digestion of one gram of fiber gives a total of 2.65 calories per gram of total crude fiber as representing the work of mastication together with the extra expenditure of energy in digestion.

COMPUTATION OF AVAILABLE ENERGY.

In brief, then, Zuntz and Hagemann compute the available energy, or maintenance value, of a feeding stuff for the horse as follows: First, the metabolizable energy is computed at the rate of 3.96 calories per gram of total digestible matter, including the digestible crude fiber and the digestible fat multiplied by 2.4. Second, from the metabolizable energy thus computed there is subtracted 9 per cent for the work of digestion and in addition 2.65 calories for each gram of total crude fiber present.

The method of computation may be conveniently illustrated from the data given by Langworthy[1] for timothy hay. Zuntz and Hagemann's factors, recalculated per pound for convenience, become, for metabolizable energy, 1.796 therms; for crude fiber, 1.202 therms. On this basis the calculation of the available energy of the hay would be as follows:

Available energy in 100 pounds of timothy hay.

Digestible nutrients:	Pounds.	
Protein	1.25	
Crude fiber	12.39	
Nitrogen-free extract	21.29	
Fat (1.18×2.4)	2.83	
	37.72	
Total crude fiber	29.00	
		Therms.
Metabolizable energy (1.796 therms×37.72)		67.75
Work of digestion:	Therms.	
9 per cent of metabolizable (67.75 therms×0.09)	6.10	
Additional for crude (1.202 therms×29)	34.86	
Total		40.96
Available energy (maintenance value)		26.79

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[1] U. S. Department of Agriculture, Office of Experiment Stations, Bulletin 125, p. 14.

As is evident from the brief description given of the methods by which the factors are reached, this method of computation is not claimed by its authors to be scientifically exact, but they believe it to be a sufficiently close approximation on which to base computations of rations in practice.

Zuntz and Hagemann's conclusions have been subjected to considerable criticism, the two principal points being, first, their estimate of 9 per cent for the work of digestion, based upon the results of experiments on man; and, second, and more especially, the assumption that the metabolism for 24 hours may be computed from the results of comparatively short respiration experiments. Qualitatively, Zuntz and Hagemann have clearly demonstrated the very considerable expenditure of energy by the horse in the digestion of his feed, as well as the fact that this expenditure is much greater with coarse fodders than with grain, and they were the first to point out that this expenditure of energy must be taken account of in estimating the values of feeding stuffs. There may be a difference of opinion as to the quantitative worth of their figures, and certainly investigations by more direct methods, involving fewer assumptions and complex calculations, are greatly to be desired, but until such results are obtained we may continue to use provisionally those reached in the manner just described.

AVAILABILITY FOR THE HORSE—WOLFF'S RESULTS.

His extensive investigations upon the working horse, made at Hohenheim in 1877 to 1894[1] and antedating the investigations thus far mentioned, led Wolff to a still simpler approximate method of estimating what in a sense corresponds to the available energy of the feed of the horse.

In Wolff's experiments, the horse performed a measured amount of work which was so adjusted in different periods as to be as nearly as possible in equilibrium with the feed consumed. This was considered to be the case when the live weight of the animal remained substantially unchanged for a considerable period and when the urinary nitrogen did not show an increase as a consequence of the additional work done. By comparing the work performed on a basal ration with that which could be done with a heavier one, the ratio of the work done to the additional feed consumed was established within the limits of error of the method, this being the prime object of the experiments. This being determined, however, it was a simple matter to compute the amount of feed corresponding to the total work done, while subtracting this from the total ration would give the maintenance ration. The results of these comparisons, made on the basis of the so-called "digestible nutrients" of the rations (the digestible fat being multiplied by 24) are considered on subsequent pages.

On the average of a considerable number of comparisons, it was found that the digestible nutrients from coarse fodders were less efficient both for work production and for maintenance than were those derived from grain, and Wolff also cites the results of Grandeau and Le Clerc's experiments in Paris which show the same general result. Wolff shows, however, that if the digestible crude fiber be omitted from the comparisons, the ratio between fiber-free nutrients and the work performed is comparatively uniform and also that this assumption yields uniform results for the fiber-free nutrients required for maintenance. He therefore concludes that the crude fiber in the rations of the horse is apparently valueless and that the remaining digestible nutrients may be regarded as of equal value whether derived from grain or from coarse fodders. Expressed in the light of our present conceptions, this is practically equivalent to saying that the expenditure of energy in digestion is proportional to the metabolizable energy of the crude fiber, or that the available energy is proportional to the amount of fiber-free nutrients.

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[1] Compare pp. 57 to 62.

Wolff is careful to say that the digestible crude fiber is *apparently* valueless, and virtually regards the amount of crude fiber as furnishing a convenient empirical measure of the difference in the nutritive value of the digestible nutrients of coarse fodder as compared with those of grain. That such is the case is doubtless explained in part by the rather limited variety of feeding stuffs employed in the experiments. The coarse fodder was meadow hay, with, in some cases, a small addition of straw, while the grain was usually oats, partially replaced in some cases by other feeds. Whether the same relation between fiber-free nutrients and work done would hold in widely different rations is not apparent.

It should be borne in mind that in reality Wolff's results are relative only. They do not show the actual amount of available energy in the feed or ration, but only that it is proportional to the fiber-free nutrients. The energy of the latter would differ considerably from the available energy as computed by Zuntz and Hagemann's method, first, because it does not include the deduction of 9 per cent for digestive work; and, second, because it assumes a uniform value of zero for crude fiber, while Zuntz and Hagemann's method gives the crude fiber a negative value if it has a digestibility of less than 55 per cent. The values computed according to Wolff's method from the fiber-free nutrients are therefore considerably higher than Zuntz and Hagemann's figures.

AVAILABILITY FOR CARNIVORA.

For many years it was taught, in accordance with Rubner's theory of "isodynamic replacement" (compare p. 72), that with carnivora the nutrients were of value in proportion to their content of metabolizable energy. Rubner's own later investigations,[1] however, have shown that what is true of the feeding stuffs consumed by horses and cattle is also true of nearly pure nutrients fed to dogs. With these subjects it is possible to use the fasting state as the basis of comparison, which considerably simplifies the investigations. The experiments were made at a comparatively high temperature, namely, about 33° C., a fact which is of importance, as will appear later, in the interpretation of the results.

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[1] Die Gesetze des Energieverbrauchs bei der Ernährung.

An experiment in which nearly enough fat was fed to supply the requirements of the organism for energy gave the following results per kilogram live weight, stated in a form which is somewhat different from that used by Rubner but which in substance is identical with it:

Availability of energy of fat—Rubner.

	Metabolizable energy of feed per kilogram live weight.	Loss by body per kilogram live weight.
	Calories.	*Calories.*
Fat fed	53.4	7.5
Fasting	0	54.0
Difference	53.4	46.5
Percentage available	87.08	....

This result appears somewhat remarkable in view of the fact that the comparison is virtually with body fat. Literally interpreted, it means that the energy of feed fat is only 87 per cent as valuable as the energy of body fat plus a little protein. If this be true, it implies a larger expenditure of energy in the digestion of fat than now seems probable, since the katabolism of resorbed feed fat can hardly differ greatly from that of body fat. Rubner's figure is the result of a single experiment and unfortunately it enters into the computation of all the other results. A redetermination of this factor is much to be desired.

In two other experiments, lean meat nearly equivalent to the maintenance requirement was fed. The meat contained a small amount of fat, the average metabolizable energy of the feed per kilogram live weight being distributed as follows:

	Calories.
In protein	56.70
In fat	4.95
	61.65

Using the data afforded by the experiment on fat, the availability of the energy of the protein may be computed as follows:

Availability of energy of protein—Rubner.

	Metabolizable energy of feed per kilogram live weight.	Loss by body per kilogram live weight.
	Calories.	*Calories.*
Meat fed	61.65	8.90
Fasting	0	51.50
Difference	61.65	42.60
Difference due to fat	4.95	4.31
Difference due to protein	56.70	38.29
	Per cent.	
Percentage available	67.53	....

The difference between the percentage available and 100 shows, of course, the proportion of the metabolizable energy of the feed which was expended in increasing the total metabolism as measured by the heat production. This increase of the metabolism of the body is called by Rubner the "specific dynamic effect" of the several nutrients. Rubner's final average results are contained in the following table. It should be clearly understood that they are not applicable to the "digestible nutrients" of the feed of herbivora.

Average availability—Rubner.

	Availability.	Specific dynamic effect.
	Per cent.	*Per cent.*
Body protein	68.1	31.9
Meat protein	69.1	30.9
Gelatin	72.0	28.0
Fat	87.3	12.7
Cane sugar	94.2	5.8

CAUSES OF INCREASED METABOLISM.

The foregoing paragraphs have dealt with the fact of the increased metabolism and consequent heat production resulting from the ingestion of feed without considering the cause of the increase. Two explanations of it naturally suggest themselves. The first is that the greater supply of the various nutrients directly stimulates the metabolism of the body cells, while the second ascribes the increased metabolism to the additional expenditure of energy required for the digestion of the feed and its preparation for metabolism in the actual vital processes. The latter explanation is the one which has been generally accepted, although by no means without dissent,[1] and the expenditure of energy for these purposes has been somewhat loosely and perhaps not altogether fortunately designated as the "work of digestion." A consideration of some of the processes connected with the consumption of feed which lead to the liberation of energy may serve to clarify the conception.

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[1] Compare Heilner, Zeitschrift für Biologie, vol. 48, p. 144; vol. 50, p. 488.

MECHANICAL WORK.

Digestion requires more or less mechanical work in the prehension and mastication of the feed and in moving it through the digestive organs. In this connection, too, it should be remembered that the feed in this sense includes the water as well, three or four parts of water being usually consumed by herbivora for each part of dry matter in the feed. As noted on p. —, Zuntz and Hagemann have compared the metabolism of the horse while eating with that of the same animal while at rest and computed from the difference the amount of energy expended in mastication. The following recapitulation of some of their results shows the number of calories of energy expended in the mastication of 1 kilogram of the material named:

	Calories.
Hay	167.5
Green alfalfa	30.4
Oats	47.0
Maize	13.8

Kellner[1] has investigated the effect of the grinding of straw upon its value in a productive ration. He finds that the practical elimination in this way of the work of mastication reduces the expenditure of energy by approximately 0.66 calorie for each gram of crude fiber present in the straw.

That the movement of the masticated feed through the digestive tract must also require an expenditure of energy is obvious, but no data are available as to its amount.

SECRETION.

The secretion of the digestive fluids likewise requires some expenditure of energy. This has been shown by direct experiment to be true of the salivary glands and the pancreas and is also true, doubtless, of the other digestive glands. Apparently, however, the amounts of energy thus expended are comparatively small.

FERMENTATION.

The extensive fermentations occurring in the digestive tract of herbivora result in a considerable evolution of heat. The most important of these is the methane fermentation. Assuming on the basis of Tappeiner's results[2] that 100 grams of carbohydrates yield 4.7 grams of methane and 33.5 grams of carbon dioxid, and assuming further that two-thirds of the carbon of the organic acids produced is contained in acetic acid and the remainder in butyric, it may be computed that the heat evolved amounts to 12.5 per cent of the total energy of the digested carbohydrates or 0.523 calorie per gram. It should be noted that this estimate does not refer to the potential energy carried off in the methane, but to the heat evolved in the fermentation. The latter is part of the metabolizable energy of the carbohydrates, since it is liberated in the kinetic form in the body, but since it takes at once the form of heat, it is not available energy in the sense in which the term is here used.

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[1] Die Ernährung der Landwirtschaftliche Nutztiere, 5th ed., p. 163.

[2] Zeitschrift für Biologie, vol. 20, p. 52.

The same general considerations, of course, apply to the other fermentations and putrefactions which occur in the digestive tract, but their amount in herbivora is probably small compared with that of the methane fermentation, and we have relatively little knowledge regarding them.

DIGESTIVE CLEAVAGES.

It is well known that extensive cleavages of the feed ingredients occur in the digestive tract. The nutrients, by the action of the digestive ferments, are split up into simpler atomic groupings—the so-called building stones of the molecule—out of which the proteins, carbohydrates, and fats peculiar to the animal body are built up. One argument which has been brought forward in the past against the extensive occurrence of such cleavages in natural digestion, especially of the proteins, has been the teleological one that the splitting up into these comparatively simple compounds was a waste of valuable nutritive material. On the other hand these processes have been invoked to explain the striking effect of the proteins in stimulating the metabolism—their large specific dynamic effect, to use Rubner's terminology. So far as the peculiar use of protein in the body is concerned, it is well established that its crystalline cleavage products can be resynthesized to form protein. It is of special interest, therefore, to learn that these cleavages and resyntheses are apparently nearly isothermic processes. Some of the cleavage products of protein contain more potential energy per gram than protein itself, as, for example, leucin, with 6.525 calories per gram, and tyrosin, with 5.916 calories per gram. Others, like alanin, with a heat of combustion of 4.356 calories, contain but little less energy than the protein from which they are derived. Even the simplest amino-acid, glycocol, resulting from this cleavage has a heat of combustion of 3.129 calories per gram. The impression which these figures give—that but little energy is lost in the cleavage of the proteins—is confirmed by direct experiments. Loewi[1] found the dry residue of the tryptic digestion of meat to have an energy value of 4.6 calories per gram. Tangl, Lengyel, and Hari[2] found the products of the peptic or tryptic digestion of egg albumin and serum albumin to contain nearly or quite as much potential energy as the original protein. Grafe[3] has made artificial digestions of protein in a calorimeter, and found no noticeable evolution or absorption of heat. It seems safe, therefore, to regard the digestive cleavage of protein as at least a nearly isothermic process, causing little loss of energy in digestion.

Substantially the same thing is true of the digestive cleavage of carbohydrates and fats. Thus 1 gram of starch yields 1.111 grams of dextrose, and the heats of combustion of these quantities are, respectively, 4.183 calories and 4.159 calories, showing a loss of less than 0.6 per cent. One gram of sucrose yields 0.5264 gram each of dextrose and levulose, and the energy values are, respectively, 3.955 calories and 3.947 calories, or a loss of less than 0.2 per cent So, too, 1 gram of tristearin with a heat of combustion of 9.43 calories yields by hydrolysis 0.9573 gram of stearic acid, equivalent to 9.026 calories, and 0.1033 gram of glycerin, equivalent to 0.424 calorie, or a total of 9.45 calories.

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[1] Leathes. Problems in Animal Metabolism, p. 129.

[2] Archiv für die gesammte Physiologie des Menschen und der Thiere (Pflüger), vol. 115, p. 1.

[3] Jahresbericht über die Fortschritte der Tier Chemie, vol. 37, p. 917.

INTERMEDIARY METABOLISM.

The chemical reactions taking place during the so-called intermediary metabolism of the resorbed material before it is finally utilized for the vital processes have also to be considered as possible sources of heat production, although our present knowledge of them is meager.

This possibility is of special interest in connection with the marked effect of protein on the energy metabolism, since this can hardly be ascribed to digestive work in the strict sense. In the normal digestion of protein fermentations play a very small part, while, as just shown, the digestive cleavage of protein is substantially isothermic. Neither can we imagine that the mechanical work of digestion or the secretion of digestive juices can account for the large expenditure of energy. Rubner[1] has reported experiments in which the protein katabolism of the fasting animal was artificially increased by the administration of phlorhizin, and in which a similar increase in the heat production is computed, although there could have been no digestive work in the strict sense. Falta, Grote, and Stählein[2] have found that the products of the tryptic digestion of casein when fed to a dog produce nearly as great an increase in the metabolism as does a corresponding amount of casein, while in the familiar experiments of Zuntz and Mering[3] the intravenous injection of the crude products of the peptic digestion of blood fibrin had a like effect.

The katabolism of protein seems to consist in outline, first, of a hydrolytic cleavage into peptids and amino-acids and, second, in a deamidization of these latter compounds, and it is the nonnitrogenous products resulting from this deamidization which serve as a source of energy for the body, the nitrogen being split off as ammonia and excreted as urea. It is to a liberation of energy in the form of heat in these preliminary processes of preparing protein to serve as fuel that Rubner and other authors ascribe its specific dynamic effect.

Our knowledge of the intermediary metabolism of protein is too meager to render any quantitative estimate of the amount of energy lost in this way of much value. The cleavage of protein, as noted, seems to be substantially isothermic. The deamidization of the simpler amino-acids with a small number of carbon atoms seems at first thought to involve considerable loss of energy. For example, the potential energy of 1 gram of glycocol and of alanin and of equivalent amounts of acetic and propionic acids are:

	Glycocol.	Alanin.
	Calories.	*Calories.*
Energy of amino acid	3.129	4.356
Energy of equivalent fatty acid	2.791	4.129
Difference	.338	.227
Percentage loss	10.8	5.2

A similar comparison of alanin with the equivalent amount of lactic acid shows an apparent loss of about 14 per cent. With the higher members of the series, the loss computed in this way is relatively small. It must be remembered, however, that the amino group is split off as ammonia, which also contains potential energy equal, according to Ostwald, to 3.319 calories per gram in the gaseous state. If we assume that the alanin yields lactic acid with a heat of combustion of 3.7 calories per gram we may make the following comparison:

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[1] Gesetze des Energieverbrauchs bei der Ernährung.

[2] Beiträge zur Chemischen Physiologie und Pathologie, vol. 9, p. 372.

[3] Archiv für die gesammte Physiologie des Menschen und der Thiere (Pflüger), vol. 32, p. 199.

	Calories.	Calories.
Energy of 1 gram alanin		4.356
Energy of 1.011 grams lactic acid	3.742	
Energy of 0.191 gram ammonia	0.634	
		4.376
Difference		.020

In other words, it would appear that the deamidization of the amino acids, like the antecedent cleavage of the proteins, is a nearly isothermic reaction and that we must seek elsewhere for the explanation of the specific dynamic effect of protein. We can by no means assert, however, that the protein katabolism actually takes place according to this simple scheme, nor that the nonnitrogenous substances resulting from deamidization of the amino acids yield their energy without loss. It seems not unlikely that the higher fatty acids and other nonnitrogenous derivatives of protein are broken down by cleavage and otherwise to comparatively simple molecules before they are finally oxidized, and there is the possibility of more or less loss of energy in such processes.

As already indicated, Rubner explains the specific dynamic effect of protein from the foregoing point of view, but in a different manner. It has been shown beyond reasonable doubt that sugar is produced, or may be produced, in the katabolism of protein. According to Rubner, it is only the energy of this sugar that is capable of being used for the physiological functions of the body cells, while the energy set free in the conversion of protein into sugar is liberated as heat and constitutes the specific dynamic effect. This explanation of Rubner's, however, seems to be disproved by recent results reported by Lusk and Ringer.[1] They have shown that alanin is completely convertible to dextrose in a diabetic animal, while in the case of glutamic acid but three out of the five carbon atoms of the molecule are utilized for the production of dextrose. According to Rubner's hypothesis, therefore, alanin should show no specific dynamic effect, while glutamic acid should show a considerable one. In a preliminary communication Lusk[2] reports that neither one of these amino acids when added to a standard diet increased the excretion of carbon dioxid in the respiration. This result is in striking contrast with those of Falta, Grote, and Stählein and of Zuntz and Mering just referred to, in which the crude products of tryptic or peptic digestion were fed. They suggest that some substance other than the recognized amino-acids may be responsible for the stimulating effect of protein upon metabolism, while they likewise recall the fact that crude peptones have been found to have a poisonous effect when injected intravenously while purified peptones do not, and likewise the fact that in Zuntz and Mering's experiments purified peptones caused no increase in the metabolism.

EXCRETION.

Zuntz[3] calls attention to Barcroft's[4] experiments, which show that the excretory activity of the kidneys is accompanied by a notable increase in the amount of oxygen consumed, and sees in the work thrown on these organs by the elimination of the nitrogen of protein one of the causes of its specific dynamic effect. In experiments in collaboration with Steck he found that a marked increase of the metabolism, as computed from the oxygen consumed, followed the administration of urea, and likewise of sodium chlorid, to men and dogs. In the case of urea he computes that the effect was equal to 20 to 25 per cent of that of an equivalent amount of protein. Zuntz also calls attention to earlier experiments by Nering and Schmoll in which carbohydrates added to the diet of a diabetic produced a similar increase of metabolism, although the sugar was not assimilated but excreted unchanged. Zuntz ascribes the results obtained by Rubner to the fact that phlorhizin added largely to the increased excretory work required by the elimination of the nitrogen and of the sugar formed, pointing out also that Rubner has overestimated the amount of heat produced through failure to deduct the energy of the sugar excreted in the urine. On the other hand, in Lusk's experiments, just quoted, there was an increased excretion of urea subsequent to the administration of amino acids, but no increase in the carbon dioxide excreted, while Tangl[1] finds that the intravenous injection of urea or sodium chlorid causes an increase in the metabolism even when the kidneys have been extirpated or clamped off.

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[1] Journal of the American Chemical Society, vol. 32, p. 671.

[2] Proceedings of Society for Experimental Biology and Medicine, 1910, vol. 7, p. 136.

[3] Medizinsche Klinik, 1910.

[4] Ergebnisse der Physiologie, vol. 7, p. 744.

On the whole, it can not be said that any fully satisfactory explanation has yet been offered of the effects of feed, and in particular of protein, upon the metabolism, although certain factors, especially in domestic animals, are clearly evident.

But whatever explanation we may accept—whether, following Zuntz, we speak of work of digestion, or, with Rubner, avoid any implication as to the cause by the use of the term specific dynamic effect—the fact that the metabolizable energy of different feeding substances is not equally available for maintenance is established beyond question, and it is this fact which is of immediate importance in considering the energy requirement for maintenance and the maintenance values of feeding stuffs.

THE MAINTENANCE RATION.

In accordance with the principles laid down in the foregoing paragraphs, a maintenance ration as regards energy may be defined as one which supplies available energy equal to the fasting katabolism.

For example, in Rubner's experiment cited on page 27, in which fat was fed, the fasting katabolism of the dog was 54 calories per kilogram. Fat containing 53.4 calories of metabolizable energy diminished the loss of body tissue by 46.5 calories. Evidently, then, to reduce the loss by 54 calories, that is, to reduce it to zero, would have required $53.4\times\frac{54}{46.5}=62$ calories of metabolizable energy to be supplied in fat. The same thing may also be expressed in a slightly different way: If, as there computed, only 87.08 per cent of the metabolizable energy of fat is available, then to make good a total loss of 54 calories will require $54\div0.8708=62$ calories of metabolizable energy in fat.[1] On this basis we may compute from Rubner's final averages (p. 28) that to maintain the dog experimented on, that is, to make good the loss of 54 calories of energy per kilogram, it would have been necessary to supply per kilogram the following amounts of metabolizable energy in the materials named:

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[1] Biochemische Zeitschrift, vol. 34, p. 1.

	Calories.
In meat protein	79.3
In gelatin	78.1
In fat	61.9
In cane sugar	57.3

These figures afford a simple illustration of the fact that the amount of metabolizable energy required for maintenance is variable, being greater as its availability is less. The maintenance requirement of the dog was 54 calories of available energy. The maintenance ration needed to supply this varied according to the material which served as the carrier of the energy.

The same relations hold good for farm animals, although the fact that we can not well observe their fasting katabolism directly makes the computation a trifle more complicated. As an example, we may take the experiment on timothy hay already cited on page 20. The addition of 2.1 kilograms of timothy hay, equivalent to 3.575 therms of metabolizable energy, to the basal ration reduced the loss of energy from the body of the animal by 2.020 therms. Evidently, then, to have reduced it by 2.377 therms, that is, to zero, would have required the addition of $2.1 \times \frac{2.377}{2.020} = 2.471$ kilograms of the hay, equivalent to 4.207 therms of metabolizable energy. The total maintenance ration of this particular feeding stuff, then, would have been the basal ration plus this amount, or 5.670 kilograms of the hay, equivalent to 9.894 therms of metabolizable energy.

The same result may also be obtained by the use of the percentage availability as computed, viz, 56.5 per cent. The heavier ration failed to maintain the animal by 0.357 therms, that is, it lacked this amount of available energy. To supply this requirement would evidently demand $0.357 \div 0.565 = 0.632$ therms of metabolizable energy, which added to the 9.262 therms already contained in the ration gives a total as above of 9.894 therms. The same computation can, of course, be made from the lighter ration with the same result.

From the data given it is likewise possible to compute what the loss by the body would have been had it been practicable to withdraw all feed. The basal ration contained 5.687 therms of metabolizable energy, of which 56.5 per cent was available; that is, the basal ration was capable of preventing the loss of $5.687 \times 0.565 = 3.213$ therms from the body. Had the basal ration been entirely withdrawn, then the loss would have been increased by this amount; that is, the total loss would have been 3.213+2.377=5.590 therms. The same quantity would, of course, be obtained by starting from the heavier ration or from the maintenance ration as computed above. The fasting katabolism, which can not well be determined directly, is thus obtained by computation. In other words, this steer expended daily 5.590 therms of energy in the maintenance of his necessary vital processes aside from those connected with the digestion and assimilation of his feed. This was his maintenance requirement as defined in the foregoing paragraphs, and an amount of the clover hay which was capable of supplying this quantity of available energy, viz, 5.670 kilograms, was a maintenance ration, while on smaller amounts he drew upon his body tissues to cover the deficiency.

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[1] On the assumption, of course, that the effect is a linear function of the amount of food.

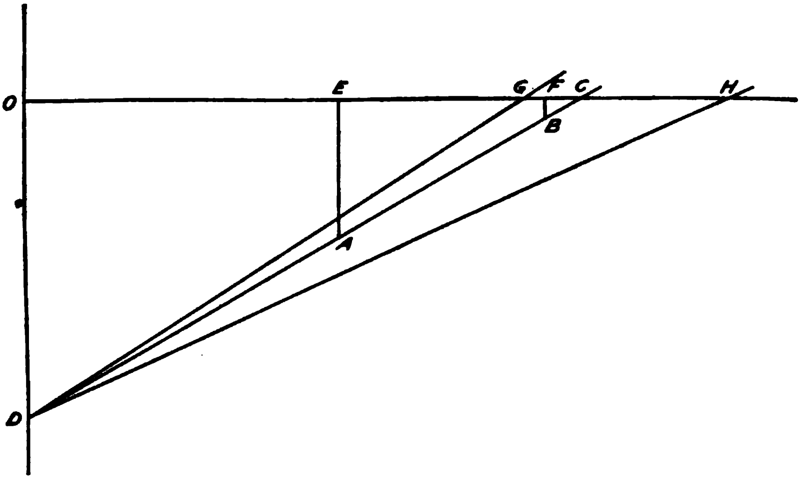

FIG. 1.—Availability of metabolizable energy of hay.

All these facts may also be conveniently represented graphically as follows:

If on the two coordinate axes of figure 1, we let the horizontal distances represent the metabolizable energy of the feed and the vertical distances the gain of energy by the body of the animal, the results of the two experiments just referred to may be represented by the points A and B, the distances OE (equal to 5.687 therms) and OF (equal to 9.262 therms) representing the amounts of metabolizable energy in the two rations and the distances EA (equal to —2.377 therms) and FB (equal to —0.357 therm) the corresponding (negative) gains of energy by the animal. A straight line drawn through A and B and intersecting the two axes at D and C will then represent the relation between the supply of metabolizable energy in the feed and the grain by the body of the animal.[1] This relation may also be expressed analytically by the equation $y=ax-m$, in which m=OD (equal to 5.590 therms) will represent the computed fasting katabolism and *a* the tangent of the angle between AB and the horizontal axis (equaling in this case 0.565), or the percentage availability, while OC (equal to 9.894 therms) is the maintenance ration in terms of the metabolizable energy of this particular hay.

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[1] Assuming that this is a linear function.

The fasting katabolism being a constant quantity under like conditions, it follows that an amount of any feed capable of supplying 5.590 therms of available energy would have been a maintenance ration for this animal. It is clear then that the actual weight of feed required for maintenance will vary inversely as the availability of its energy. With this particular hay, it would have been necessary to use an amount containing 9.894 therms of metabolizable energy. With the timothy hay used in an earlier experiment, however, 62.9 per cent of whose metabolizable energy was found to be available, corresponding to the line DG in figure 1, it would have been necessary to use a quantity containing only $5.590 \div 0.629 = 8.888$ therms, represented in the figure by OG, in order to supply the requisite available energy and secure maintenance. On the other hand, with a coarser forage having, e. g., an availability of only 45 per cent, represented by DH, it would have been necessary to supply $5.590 \div 0.45 = 12.420$ therms of metabolizable energy, represented in the figure by the line OH. Just as was illustrated previously in the case of the dog, while the real requirement of energy for the vital processes remains unchanged the amount of feed necessary for maintenance is variable, depending upon the availability of its energy.

If with Zuntz we regard the increased katabolism consequent upon taking feed as representing energy expended in its digestion and assimilation, we may state the case in a slightly different way. We may compare the work thus done to the work of placing the fuel under a factory boiler. If this is done by means of power derived from the same boiler, it is evident that the farther the fuel has to be moved and the greater the amount of incombustible waste which it contains, the larger will be the fraction of the total boiler power required simply to keep the fire going and the less the proportion available for running the factory. So in the body, the greater the amount of energy which must be expended on the food in order to prepare it for its functions in the body the less is the proportion of its energy which is available for carrying on the physiological processes.

RELATION OF MAINTENANCE REQUIREMENT TO LIVE WEIGHT.

Before taking up the specific maintenance requirements of farm animals, it is necessary to consider the influence of size and weight upon the maintenance requirement.

That large animals katabolize more matter and produce more heat than smaller ones requires no special proof. Experiment shows, however, that the difference is not proportional to size or weight, but that small animals have a relatively more intense metabolism than large ones, the amount being approximately proportional to the body surface, which, of course, is relatively greater in the smaller animal. The existence of such a relation was surmised by various writers, but we are indebted to Rubner[1] for the first quantitative investigation of this question. He determined the fasting katabolism of six dogs whose weights ranged from 3 to 24 kilograms. With the addition of earlier experiments by Voit on a still larger dog, the average results were as follows, the total katabolism being expressed in terms of computed energy.

Relation of fasting katabolism to weight and to surface—Rubner and Voit.

No. of animal.	Live weight.	Katabolism per kilogram, live weight.	Katabolism per square meter of body surface.
	Kilos.	*Calories.*	*Calories.*
I	30.66	36.66	1,046
II	23.71	40.91	1,112
III	19.20	45.87	1,207
IV	17.70	46.20	1,097
V	9.51	65.16	1,183
VI	6.44	64.79	1,120
VII	3.10	88.25	1,214

While not mathematically constant, the ratio between the fasting katabolism and the surface shows a close approximation to uniformity, and the same fact has been verified by a considerable number of subsequent experiments. Moreover, it has been shown[2] to be approximately true not only of animals of the same species, but of animals ranging in size from man to domestic fowls, and including also cold-blooded animals. A recent investigation by Kettner[3] upon 13 guinea pigs furnishes a striking illustration of this general uniformity.

Rubner explains the apparent dependence of the fasting katabolism on body surface as the consequence of the loss of heat from the body due to the cooling action of the environment, which would naturally be proportional to the surface. The fact, however, that not inconsiderable variations have sometimes been observed indicates that other factors than the elimination of heat are concerned, and apparently the true cause lies deeper. Not merely the heat production but all the important physiological activities of the body, including the expenditure of energy in locomotion, seem to be proportional to the body surface rather than to the weight, while the fact that the same law holds true for cold-blooded animals, which assume the temperature of their surroundings and which, therefore, are subjected to no demand for heat, points in the same direction. Apparently we have here a general biological law of which the proportionality between heat production and body surface is one expression.

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[1] Zeitschrift für Biologie, vol. 19, p. 535.

[2] E. Voit. Zeitschrift für Biologie, vol. 41, p. 113.

[3] Archiv für (Anatomie und) Physiologie, 1909, p. 447.

The internal work of the animal, however, as measured by the fasting katabolism or the fasting heat production, constitutes, as we have seen, its maintenance requirement. The maintenance requirements of animals of different sizes, therefore, especially of those of the same species, are proportional to their surfaces.

COMPUTATION OF RELATIVE BODY SURFACE.

Few actual determinations of the body surface of animals have been made and almost none for farm animals, so that it is at present impossible to express with accuracy the metabolism of the latter animals per unit of surface. For purposes of comparison between individuals of the same species, however, another method serves to give at least approximate results. It is a familiar geometrical fact that the surfaces of two solids of the same shape (i. e., similar figures in the geometrical sense) are proportional to the two-thirds powers of their volumes. By regarding all animals of the same species as of the same shape and also as having the same specific gravity, so that their weights are proportional to their volumes, it is a very simple matter to compute their relative surfaces and the corresponding maintenance requirements. For examplé, a steer weighing 583 kilograms was found to have a computed fasting katabolism (i. e., maintenance requirement) of 8.671 therms. A steer weighing 500 kilograms, other things being equal, would have a maintenance requirement in proportion to its smaller surface. The latter would be to the surface of the larger animal, approximately, as $(500)^{\frac{2}{3}}$ is to $(583)^{\frac{2}{3}}$ and the maintenance requirement would therefore be $8.671 \times \left(\frac{500}{583}\right)^{\frac{2}{3}} = 7.878$ therms. In this way it is a simple matter to compute the relative maintenance requirements of different individuals without the necessity of expressing them per unit of surface.

Of course, such a comparison is only approximately correct. In the first place, it may be presumed that there are differences in the specific gravity of different individuals, although it may be doubted whether these differences are sufficiently great to be of much significance in this connection. Moreover, different animals are not of the same shape. The young animal differs in conformation from the older one, and the beef steer and the dairy cow, for example, are far from being geometrically similar. It would be of much interest to determine the relation of surface to weight in different species, types, and ages of domestic animals, but lacking such determinations the method of computation above outlined may probably be assumed to give a fair approach to the truth and is at any rate the only one available.

THE MAINTENANCE RATIONS OF FARM ANIMALS.

In endeavoring to formulate the maintenance rations of farm animals it is important to have a clear conception of the nature of the problem and to distinguish between its physiological and its economic aspects. The physiological conception of the maintenance requirement is the amount of energy required to carry on the absolutely necessary vital processes in a state of the most complete rest possible. It is the least amount on which life can be sustained; the physiological minimum; the base line for comparison. In actual practice, no such state of complete rest can be maintained for any length of time. There is necessarily superadded to the minimum physiological requirement the energy expended in a variety of ways, but especially in the numerous minor muscular movements which are unavoidable in the waking state, which may be summarized under the term incidental work. Some of the factors of this incidental work are discussed on subsequent pages. Physiologically, this additional energy is expended for production; the animal is doing work on its surroundings. Economically, however, the work done is of no value and the energy required to do it is, therefore, from that point of view, a part of the cost of maintenance. In practice, of course, it is not the physiological but the economic requirement which is of importance. The latter will necessarily be more or less variable according to the individuality of the animal and the conditions under which it is maintained, as will appear in the following discussion, and statements of maintenance requirements and rations should therefore indicate to such a degree as is possible the conditions to which they are intended to apply.

CATTLE.

The maintenance requirements of cattle have been more extensively studied than those of other species and it will be convenient to take them up first, using the data also as a means of illustrating the principles involved and the methods of investigation employed.

The estimate of the maintenance ration of cattle long current and still occasionally cited was based upon the investigations of Henneberg and Stohmann[1] in 1858. According to their results, a 1,000-pound steer required for maintenance about 8.16 pounds of digestible organic matter per day, equivalent to about 14.3 therms of metabolizable energy. In view of the rather high stable temperature in these experiments, however, Wolff[1] when formulating his well-known feeding standards increased this amount to 9.1 pounds digestible organic matter, equivalent to about 15.9 therms of metabolizable energy. Numerous subsequent experiments,[2] however, showed quite clearly that this estimate was considerably too high but without affording a sufficient basis for its correction, and it is only since 1898 that really satisfactory data have been secured.

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[1] Beiträge zur Begründung einer rationellen Fütterung der Wiederkäuer, Heft I, pp. 17–188.

One general method of experimentation has already been illustrated in the computation on pages 34–35 of the maintenance requirement of a steer. In brief, it consists of comparing the losses of body energy by the animal when fed two different amounts of the same feed or combination of feeds, each being less than the maintenance ration, and computing from the difference the amount of energy required for simple maintenance.

Investigations by Armsby and Fries[3] include eight trials with three different animals substantially upon this plan. In the later experiments of the series a correction was made for differences in live weight in the different periods of each experiment and for differences in the amount of time spent standing and lying, the results being computed to 12 hours standing. The results here given for the earlier experiments have been corrected in the same manner and therefore differ somewhat from those originally reported. The following tabulation of the results shows also, for comparison, the percentage availability of the metabolizable energy of the feed and likewise the maintenance ration expressed in terms of metabolizable energy. The results in every case have been computed to a uniform live weight in proportion to the two-thirds power of the weight. It is to be noted that the experiments are upon coarse fodder (clover and timothy hay) exclusively, and that the animals were not fat.

Maintenance requirements and rations of steers—Armsby and Fries.

Years.	Animal.	Available energy for maintenance.		Percentage availability of metabolizable energy.	Metabolizable energy for maintenance.		Feed.
		Per 500 kilograms live weight.	Per 1,000 pounds live weight.		Per 500 kilograms live weight.	Per 1,000 pounds live weight.	
		Therms.	*Therms.*	*Per cent.*	*Therms.*	*Therms.*	
1903	I	6.483	6.076	50.88	12.742	11.942	Clover hay.
1904	I	7.812	7.321	80.24	9.736	9.124	Do.
1905	A	6.649	6.231	60.51	10.988	10.297	Timothy hay.
1905	B	7.532	7.058	55.21	13.642	12.784	Do.
1906	A	6.077	5.695	[57.05]	10.652	9.982	Do.
1906	B	6.806	6.378	[56.50]	12.046	11.288	Do.
1907	A	5.186	4.860	57.05	9.090	8.519	Do.
1907	B	6.931	6.496	56.50	12.267	11.497	Do.
Average of all		6.685	6.264	59.24	11.395	10.679	
Average, omitting 1904.		6.523	6.113	56.24	11.632	10.901	
Average, 1905–1907		6.531	6.121	57.14	11.447	10.728	

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[1] Landwirtschaftliche Fütterungslehre, 2d ed., 1877, pp. 132 and 196.

[2] The Maintenance Ration of Cattle, Pennsylvania Experiment Station Bulletin 42, pp. 12–21.

[3] Bureau of Animal Industry, Bulletins 74, 101, and 128. The results reported in Bulletin No. 51 can not be computed directly in this way because the ration included a small fixed amount of linseed meal.

Omitting the results of the year 1904, which are obviously too high both as regards the maintenance requirement and the percentage availability, we obtain the following averages in round numbers:

	Available energy.	Metabolizable energy.
	Therms.	*Therms.*
Per 500 kilograms live weight	6.52	11.63
Per 1,000 pounds live weight	6.11	10.90

The variations from these averages which occur in individual cases illustrate the fact, already pointed out, that the economic as distinguished from the physiological requirement may vary considerably with different animals and under different conditions.

The experiments just cited are the only ones thus far reported in which this precise method of determining the maintenance requirement in terms of available energy has been followed. In the majority of investigations the effort has been to feed as nearly an exact maintenance ration as possible, making a correction for the small gains or losses by the animals, and the results of these experiments have usually been expressed in terms of metabolizable energy.

By far the most exact and satisfactory experiments of this sort, as well as the earliest, are those reported by Kellner from the Moeckern Experiment Station[1] in 1894 and 1896, in which the gain or loss of protein and fat (nitrogen and carbon balances) was determined by means of a Pettenkofer respiration apparatus. In these experiments the feed consisted exclusively of coarse fodder, viz, meadow hay, or, in two instances, a mixture of clover hay and oat straw. In six cases out of the eight the respiration experiments showed a small gain of protein and fat by the animal; that is, the ration was somewhat above the maintenance requirement. For example, the gains by ox A on meadow hay and the computed equivalent amounts of energy were:

	Material gained.	Equivalent energy.
	Grams.	*Therms.*
Protein	37.2	0.211
Fat	140.8	1.338
Total		1.549

In later investigations by Kellner, out of 100 units of metabolizable energy of meadow hay supplied in excess of the maintenance requirement, only 43 were recovered in the protein and fat gained by the body. To produce the gain observed in this experiment, therefore, may be computed to have required $1.549 \div 0.43 = 3.602$ therms of metabolizable energy and the ration must have contained this amount in excess of the maintenance ration. The following calculation, therefore, shows the amount of metabolizable energy of meadow hay which was necessary for the maintenance of the animal:

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[1] Die Landwirtschaftlichen Versuchs-Stationen, vol. 44, p. 370; vol. 47, p. 310; vol. 53, pp. 6–16.

		Therms.
Energy of feed		32.177
Energy of feces	11.750	
Energy of urin	1.945	
Energy of methane	2.114	
Energy of total excreta		15.809
Metabolizable energy of ration		16.368
Metabolizable energy equivalent to gain		3.602
Metabolizable energy for maintenance		12.766

This method of computing the metabolizable energy necessary for maintenance is obviously the same in principle as that employed in Armsby and Fries's experiments, differing only in the fact that the comparison is made on amounts of feed exceeding the maintenance ration. Kellner's results, however, can not be made the basis of a direct computation of the available energy required for maintenance, since it appears probable that a larger percentage of the energy of hay is available below the point of maintenance than is utilized for gain above it.[1]

In two cases (ox B and ox IV) the rations were less than the maintenance ration and the animals lost more or less protein and fat. In computing these experiments Kellner, in accordance with the ideas then generally accepted, simply added the energy equivalent to the loss of tissue to the total metabolizable energy of the feed to obtain the maintenance ration. It is evident, however, from what has subsequently been learned regarding the availability of metabolizable energy, as outlined in the foregoing paragraphs, that if, for example, ox B lost tissue equivalent to 1.498 therms it would have required more than this amount of metabolizable energy in the food to make good the loss, the quantity necessary depending upon the availability of the energy. Of the latter we have no determinations for this particular ration, but for purposes of computing a correction we may, perhaps, assume it to be the same as that found by Armsby and Fries for timothy hay, viz, about 57 per cent. On this assumption the equivalent amount of metabolizable energy which would have had to be supplied to reach the maintenance ration of ox B would have been $1.498 \div 0.57 = 2.628$ therms, a difference of 1.130 therms. For ox IV the corresponding correction is only 0.740 therm.

Making these slight changes in Kellner's original figures for these two animals for the sake of uniformity, his results are as follows:

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[1] Compare Bulletin 128, Bureau of Animal Industry, p. 59.

Maintenance rations of oxen—Kellner.

	Live weight.	Stable temperature.	Maintenance ration (metabolizable energy).		
			Per head.	Per 500 kilograms.	Per 1,000 pounds.
Thin animals:	*Kilos.*	° *C.*	*Therms.*	*Therms.*	*Therms.*
Ox V	602.1	14.7	11.675	10.316	9.668
Ox B	611.5	15.9	17.968	15.709	14.721
Ox A	619.8	15.9	12.766	11.060	10.365
Ox IV	622.8	14.9	15.861	13.701	12.840
Ox III	632.1	14.7	13.284	11.352	10.639
Ox II	632.4	15.0	14.457	12.362	11.585
Ox VI	644.0	14.8	11.771	9.944	9.320
Ox XX	671.7	16.5	15.213	12.486	11.702
Average			14.124	12.116	11.355
Average, omitting ox B			13.575	11.603	10.874
Fat animals:					
Ox 1	748.0	15.9	23.449	17.93	16.80
Ox B	750.0	15.2	19.385	14.79	13.86
Ox 3	858.0	16.1	22.162	15.46	14.49
Average			21.656	16.06	15.05

The observed maintenance ration of ox B is notably larger than that of the other animals. This animal refused to lie down during the respiration experiments and presumably, therefore, the result obtained with it is abnormally high.

Omitting this result, the maximum, minimum, and average maintenance rations per 1,000 pounds live weight were:

Metabolizable energy required for maintenance of cattle per 1,000 pounds live weight—Kellner.

	Per 1,000 pounds live weight.
Thin animals:	*Therms.*
Maximum	12.84
Minimum	9.32
Average	10.87
Fat animals:	
Maximum	16.80
Minimum	13.86
Average	15.05

If we are justified in assuming, on the basis of Armsby and Fries's results, that approximately 57 per cent of the metabolizable energy of these rations was available, then the foregoing amounts of metabolizable energy are equivalent to the following amounts of available energy:

Computed available energy required for maintenance of cattle—Kellner.

	Per 1,000 pounds live weight.	Per 500 kilograms live weight.
For thin animals:	*Therms.*	*Therms.*
Maxinum	7.32	7.81
Minimum	5.31	5.67
Average	6.20	6.61
For fat animals:		
Maximum	9.58	10.22
Minimum	7.75	8.42
Average	8.58	9.15

Both the averages and the range of the results obtained by Kellner and by Armsby and Fries for thin cattle on coarse fodder show a remarkably close agreement. The results upon fat cattle will be considered on subsequent pages.

In addition to the respiration experiments just considered, a number of live-weight experiments upon the maintenance ration of cattle have been reported.

Such trials were made by the writer at the Pennsylvania Experiment Station[1] in 1892 to 1897, the feed being either chiefly or entirely coarse fodder. The live weight was taken daily during relatively long periods and the nitrogen balance was also determined, and from these data an approximate computation of the loss of fat was attempted. The amount of methane excreted, and the corresponding loss of metabolizable energy, was calculated from the total carbohydrates digested. Computing the final results on the same assumptions as in the Moeckern experiments,[2] the results of 4 experiments each on 3 animals weighing from 400 to 500 kilograms, computed per 500 kilograms live weight, were:

Metabolizable energy in maintenance rations of steers—Armsby.

Ration.	Per 500 kilograms live weight.		
	Steer 1.	Steer 2.	Steer 3.
Chiefly or entirely coarse fodder:	*Therms.*	*Therms.*	*Therms.*
Experiment I, 1892–93	14.23	[17.09]	13.69
Experiment II, 1892–1894	13.61	13.56	12.40
Experiment VI, 1894–95	12.92	12.87	12.73
Experiment VII, 1894–95	13.03	12.76	[17.77]
Averages (omitting results in brackets)	13.45	13.06	12.94
Largely grain:			
Experiment VIII	11.72	9.15	10.70

Assuming, as before, that about 57 per cent of the metabolizable energy was available, and omitting the two apparently exceptional results, the maximum, minimum, and average results are:

Ration.	Metabolizable energy.		Available energy.	
	Per 500 kilograms live weight.	Per 1,000 pounds live weight.	Per 500 kilograms live weight.	Per 1,000 pounds live weight.
Coarse fodders:	*Therms.*	*Therms.*	*Therms.*	*Therms.*
Maximum	14.23	13.34	8.11	7.60
Minimum	12.40	11.62	7.07	6.62
Average	13.15	12.32	7.50	7.02
Largely grain	10.52	9.86	6.00	5.62

The results on coarse fodders are materially higher than those of the respiration experiments just cited, but the method is, of course, much less accurate.

Haecker[3] reports determinations of the maintenance rations of dry cows made in three successive years and in which three different animals were used. In these experiments the nutrients digested were determined directly and the sufficiency of the ration judged of from the live weight and appearance of the animals. Results obtained by Kellner[4] and by Armsby and Fries[5] show that the metabolizable energy does not vary greatly from 1.6 therms per pound (3.5 therms per kilogram) of total digestible organic matter, even in rations differing widely as to the kinds of feed used. From the data regarding the digestible matter of the rations, therefore, the equivalent amounts of metabolizable energy may be estimated on this basis. Computing the results per 1,000 pounds in proportion to the two-thirds power of the live weight, instead of directly as does Haecker, the results are as follows:

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[1] Pennsylvania Experiment Station, Bulletin 42.

[2] This differs somewhat from the method of computation followed in the original report of the experiments.

[3] Minnesota Experiment Station, Bulletin 79.

[4] Die Landwirtschaftlichen Versuchs-Stationen, vol. 53, pp. 440–445.

[5] Bureau of Animal Industry, Bulletins 51, 74, 101, and 128.

Maintenance rations of dry cows—Haecker.

Cow.	Year.	Average live weight.	Average daily gain in live weight.	Kind of feed.	Metabolizable energy.	
					Per head.	Per 1,000 pounds live weight.
		Pounds.	*Pound.*		*Therms.*	*Therms.*
Alice	1896-97	808	0	Corn fodder	7.92	9.13
Belle	1896-97	1,010	0		9.26	9.19
Average						9.16
Belle	1897-98	1,072	0.27	Corn fodder, beets, and oil meal.	10.16	9.71
Lottie	1897-98	706	.27		7.01	8.83
Lottie	1898-99	757	.16	Not stated	8.96	10.75
Average						9.76
Average of all						9.51

In the first year's experiments the amount of digestible protein fed was small and the condition and appearance of the animals were not satisfactory. In the second and third years the rations were richer in protein, a slight gain in live weight was made, and the condition of the animals was entirely satisfactory at the close of the experiment. Since some gain was made in the second and third years the amount consumed was naturally somewhat larger than the first year. The proportion of grain to coarse fodder in the rations is not stated, but the results of the digestion trials indicate that it must have been small. If we assume 60 per cent availability, the computed available energy of the rations per 1,000 pounds live weight is:

	Therms.
Maximum	6.45
Minimum	5.30
Average of all	5.71

The results as thus computed run materially lower than those obtained at Moeckern and at the Pennsylvania station, in spite of the fact of a gain in live weight.

Evvard[1] fed three yearling steers for 60 days and one for 362 days on rations so adjusted and varied as to very exactly maintain their live weight, the average daily gain or loss being practically negligible. The experiment in the case of the first three animals followed a 30-day period in which a submaintenance ration was fed and the animals were therefore only in medium condition.[2]

The rations fed differed from those of the experiments previously quoted in containing a much larger proportion of grain, consisting of 4 parts by weight of alfalfa hay and 10 parts of mixed grain.[3] Evvard computes the available energy of the rations consumed from the data given in Bulletin 71 of the Pennsylvania station with the following results:

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[1] Thesis for degree of M. S., University of Missouri, 1909.

[2] The animals graded in the maintenance period as follows: No. 500, common; No. 598, common; No. 596, good to medium; No. 595, medium.

[3] Eight-ninths corn chop and one-ninth old process linseed meal.

Maintenance rations of yearling steers—Evvard. (First experiment.)

No. of animal.	Length of experiment.	Average live weight.	Estimated available energy per day.	
			Per head.	Per 1,000 pounds[1] live weight.
	Days.	*Pounds.*	*Therms.*	*Therms.*
590	60	608	5.63	7.85
598	60	461	3.85	6.45
596	60	464	4.34	7.25
595	362	609	5.83	8.09

[1] Computed in proportion to the two-thirds power of the live weight.

In addition to the uncertainty attaching to such live-weight experiments, as well as to the fact that the available energy was estimated, there is also a special difficulty in determining the true maintenance requirement of growing animals, which will be referred to later. Nevertheless, the results appear to agree fairly well with those obtained in the respiration calorimeter experiments.

The metabolizable energy of the rations, also computed from the data given in Bulletin 71 of the Pennsylvania station, is, on the other hand, lower than that found in either the Pennsylvania or the Moeckern experiments, although agreeing well with Haecker's results on dry cows, viz, per 1,000 pounds live weight:

	Therms.
No. 590	10.42
No. 598	8.57
No. 596	9.63
Average	9.54

Evvard's first three animals were also fed a maintenance ration of the same feeds in the same proportions for 120 days after having been previously fed heavier rations for 127 days, during which No. 590 received about one-fourth of full feed, No. 598 about one-half, and No. 596 full feed. The results of this second maintenance period are summarized in the following table:

Maintenance rations of yearling steers—Evvard. (Second experiment.)

No. of animal.	Length of experiment.	Average live weight.	Estimated available energy per day.	
			Per head.	Per 1,000 pounds live weight.[1]
	Days.	*Pounds.*	*Therms.*	*Therms.*
590	120	706	6.47	8.15
598	120	665	6.44	8.45
596	120	860	9.66	10.62

[1] Computed in proportion to the two-thirds power of the live weight.

The data contained in the foregoing pages may be summarized in the following table showing the maximum, minimum, and average maintenance rations in various experiments. Armsby and Fries's results, as already noted, have been corrected to 12 hours standing. No statement of the amount of time passed standing and lying, respectively, is given in the reports of the other experiments.

Daily maintenance rations of cattle per 1,000 pounds live weight.

Investigators.	Condition of animals.	Number of animals.	Number of single trials.	Metabolizable energy. Maximum.	Metabolizable energy. Minimum.	Metabolizable energy. Average.	Available energy. Maximum.	Available energy. Minimum.	Available energy. Average
				Therms.	*Therms.*	*Therms.*	*Therms.*	*Therms.*	*Therms.*
Armsby and Fries	Thin	3	7	12.78	8.52	10.90	7.06	4.86	6.11
Kellner	do	7	7	12.84	9.32	10.87	7.32	5.31	6.20
Do.	Fat	3	3	16.80	13.86	15.05	9.58	7.75	8.58
Armsby (coarse fodder).	Thin	3	10	13.34	11.62	12.32	7.60	6.62	7.02
Armsby (much grain).	do	3	3	10.98	8.57	9.86	6.26	4.88	5.62
Haecker	do	3	5	10.75	8.83	9.51	6.45	5.30	5.71
Evvard, 60-day experiment.	do	3	3	10.42	8.57	9.54	7.85	6.45	7.18
Evvard, 362-day experiment.	do	1	1			10.74			8.09
Evvard, second experiment.	Partly fattened.	3	3				10.62	8.15	9.07
Average of all experiments.	Thin	*20*	*36*	*13.34*	*8.52*	*10.50*	*7.85*	*4.86*	*6.31*
	Fat	*6*	*6*			*15.05*			*8.83*
Average of respiration experiments.	Thin	*10*	*14*	*12.84*	*8.52*	*10.89*	*7.32*	*4.86*	*6.10*

The foregoing results justify the statement that the maintenance ration of thin cattle, expressed in terms of available energy, ranges in general from 5 to 7.5 therms per 1,000 pounds live weight, averaging a little above 6 therms. The maintenance ration of fat animals appears to be distinctly greater than that of thin ones.

It should be noted that the term available energy is used in the sense defined on pages 20–22, as determined by a comparison of experiments upon submaintenance rations. This available energy is not necessarily identical with the energy values in terms of which the values of feeding stuffs and the requirements of animals have been expressed by Kellner and others (compare Farmers' Bulletin 346), since his results were obtained by a comparison of supermaintenance (productive) rations. Such scanty data as are now on record seem to indicate that the two are substantially the same in case of concentrated feeds, but that the available energy of coarse feeds below maintenance may be greater than their productive values above the point of maintenance. If this should prove to be the case, then evidently an estimated requirement of 6 therms of Kellner's production values will give a maintenance ration ample for practical purposes, but which will be a somewhat too large deduction to make in estimating the productive part of the ration.

SHEEP.

Data regarding the maintenance rations of sheep are less complete than for those of cattle. No experiments are on record in which the requirement of available energy has been directly determined, and but few respiration experiments have been made. Most of the recorded data are based upon live-weight experiments.

In 1867–68 Henneberg and his associates[1] conducted a series of respiration experiments upon two mature sheep receiving approximately a maintenance ration of meadow hay. Two digestion experiments, including determinations of the nitrogen balance, were made with each of the animals. During each of these digestion experiments three respiration experiments were made upon the two animals together. The results of these determinations vary so little that their average is sufficient for our present purpose. Estimating, as in some of the experiments on cattle, that each kilogram of digestible organic matter contains approximately 3.5 therms of metabolizable energy, and further, that, as in the case of Kellner's steers, 43 per cent of the metabolizable energy of the feed could be stored up in the form of gain of flesh and fat, the following computation per day and head may be made:

Maintenance ration of sheep—Henneberg and Stohmann.

Live weight, exclusive of wool	kilograms	45.4
Digestible organic matter per day	grams	539.1
Gain by animal:		
Protein	do	7.95
Fat	do	13.75

	Therm.		Therms.
Metabolizable energy of ration 0.5391×3.5			1.887
Metabolizable energy equivalent to gain:			
Protein, 0.00795 kilo.×5.7	0.0453		
Fat, 0.01375 kilo.×9.5	.1306		
	.1759	÷0.43	.409
Metabolizable energy for maintenance			1.478

The foregoing ration is equivalent to 1.574 therms per 50 kilograms, or 1.475 therms per 100 pounds, computed in proportion to the two-thirds power of the live weight.

In 1872 Henneberg, Fleischer, and Müller[2] began a series of respiration experiments upon sheep in which wheat gluten was added to a basal ration of hay and ground barley. The basal ration of the first period proved to be but slightly greater than the maintenance ration. Making the same calculations as before, but assuming that 50 per cent of the metabolizable energy of the ration might serve for the production of gain, since a portion of the ration consisted of grain, we have the following:

---

[1] Neue Beiträge, etc., pp. 68–286.

[2] Jahresbericht der Agriculturchemie, vol. 16–17, II, 145.

Maintenance ration of sheep—Henneberg, Fleischer, and Müller.

Live weight	kilograms		34.20
Digestible organic matter per day	grams		562.94
Gain by animal:			
Protein	grams		1.94
Fat	grams		43.60
			Therms.
Metabolizable energy of ration 0.56294×3.5			1.970
Metabolizable energy equivalent to gain—			
		Therm.	
Protein, 0.00194×5.7		0.01106	
Fat, 0.0436×9.5		.41420	
		.42526 ÷ 0.50	.851
Metabolizable energy for maintenance			1.119

This result is equivalent to 1.441 therms per 50 kilograms or 1.350 therms per 100 pounds live weight.

Hagemann,[1] from the results of a digestion and metabolism experiment and of 42 short[2] respiration periods with the Zuntz type of apparatus on a mature sheep averaging 50.33 kilograms live weight, computes an approximate energy balance which may be put in the following form, assuming that 50 per cent of the surplus metabolizable energy of the mixed ration might be recovered as gain:

Maintenance ration of sheep—Hagemann.

		Income.	Outgo.
		Therms.	*Therms.*
Feed:			
Alfalfa hay		2.181	
Corn meal		1.524	
Uneaten			0.009
Excreta:			
Feces			1.332
Urine			.146
Gain:	*Therm.*		
1.44 grams protein	0.008		
46.20 grams fat	.439		
	.447 ÷ 0.50		.914
Maintenance			1.304
		3.705	3.705

In addition to the foregoing experiments there are a number of digestion experiments by Wolff, in which the live weight of the animals was approximately maintained. In 1871[3] two series of experiments were made upon the relative digestive power of three breeds of sheep for an approximate maintenance ration. A comparison of the live weights of the animals is possible only for the second series, in which the ration consisted of clover hay and potatoes. The total organic matter digested per day and head and the average live weights at the beginning and end of the experiment were as given in the table, which also shows the metabolizable energy equivalent to the digested organic matter (3.5 therms per kilogram), both per head and per 50 kilograms live weight, computed in proportion to the two-thirds power of the latter. The average result is equivalent to 1.634 therms per 100 pounds live weight.

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[1] Archiv für (Anatomie und) Physiologie, 1899, Suppl., p. 138.

[2] Usually not exceeding 30 to 40 minutes.

[3] Landwirtschaftliche Jahrbücher, vol. 1, p. 533.

Maintenance rations of sheep—Wolff.

Breed.	Number of animals.	Live weight.[1]		Digested organic matter per day and head.	Equivalent metabolizable energy per day.	
		Initial.	Final.		Per head.	Per 50 kilograms live weight.
		Kilos.	*Kilos.*	*Grams.*	*Therms.*	*Therms.*
Electoral merino	1	39.85	39.20	345.35	1.209	1.414
	2	42.05	40.50	342.34	1.198	1.361
Natives	3	49.85	49.50	537.97	1.883	1.891
	4	47.45	47.20	523.24	1.831	1.898
Southdowns	5	67.55	66.20	680.43	2.382	1.963
	6	59.05	59.70	620.38	2.171	1.936
Average					1.779	1.744

[1] Average of 5 or 6 consecutive days.

In 1892–93 Wolff[1] made a series of experiments with sheep on the influence of salt upon digestibility. In the first two periods of this series an approximate maintenance ration of 1,000 grams of meadow hay per day and head was fed. Since the salt was found not to affect the digestibility of the feed, we may use the results of the two periods as a basis for computing the maintenance ration. The average live weights per head were as follows:

	January 2, 3, and 4.	February 5, 6, and 7.
Sheep No. 1	42.9	44.0
Sheep No. 2	43.8	42.8
Sheep No. 3	42.8	44.5
Sheep No. 4	42.2	42.0
Average	42.9	43.3

The feed consumption was uniform with all the animals and the percentage digestibility showed but very slight variations, so that we may regard the average of the eight trials as representing approximately the maintenance ration. The average amount of organic matter digested per day and head was 476.28 grams. Reckoning, as before, 3.5 therms of metabolizable energy per kilogram, this corresponds to 1.667 therms per head, equivalent to 1.841 therms per 50 kilograms or 1.725 therms per 100 pounds live weight, computed in proportion to the two-thirds power of the latter.

Wolff[2] has also computed the digestible matter in the rations consumed by sheep in a number of the earlier experiments by Henneberg. The average of six rations which appeared amply sufficient for maintaining the live weight of the animal was, per head:

	Kilograms.
Live weight	40.05
Organic matter digested	.566
Equivalent metabolizable energy ... therms	1.981

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[1] Landwirtschaftliche Jahrbücher, vol. 25, p. 175.

[2] Ernährung der Landwirtschaftliche Nutztiere, pp. 416–419.

Computed in the usual way, this is equivalent to 2.300 therms per 50 kilograms. This is a much higher result than was obtained in any of the other experiments, and in view of the fact that the digestibility of the rations was estimated and that the feed was of a somewhat varied character it seems permissible to omit this result from consideration.

The results of the experiments cited, omitting the ones last mentioned, may be summarized as follows:

Daily maintenance rations of sheep.

Kind of experiment, and investigator.	Metabolizable energy.	
	Per 50 kilograms live weight.	Per 100 pounds live weight.
Respiration experiments:	*Therms.*	*Therms.*
Henneberg and Stohmann	1.574	1.475
Henneberg, Fleischer, and Müller	1.441	1.358
Hagemann	1.304	1.222
Average	1.440	1.352
Digestion experiments:		
Wolff, 1871, 6 experiments	1.744	1.634
Wolff, 1892–3, 8 experiments	1.841	1.725
Average	1.793	1.680
Average of all	1.581	1.483

It is of some interest to compare this average maintenance ration of sheep with the corresponding results for cattle. If we assume that the surfaces exposed by these two species are roughly proportional to the two-thirds powers of their live weights, the corresponding maintenance ration for a 1,000-pound steer would be $1.483 \times \left(\frac{1000}{100}\right)^{\frac{2}{3}} = 6.885$ therms of metabolizable energy as compared with an average of 10.50 therms for cattle. While such a comparison is, of course, but a rough approximation, it nevertheless seems to show conclusively that the metabolism of the sheep per unit of surface is distinctly lower than that of cattle. No obvious reason for such a difference suggests itself. That it can hardly be due to the direct effect of the wool in diminishing the radiation of heat will appear from a discussion, in a later section, of the influence of external temperature on the maintenance requirement.

SWINE.

Two determinations of the fasting katabolism of swine have been reported by Meissl, Strohmer, and Lorenz.[1] The experiments were made with the respiration apparatus, no calorimetric determinations being carried out.

Computing the energy katabolized by the use of Rubner's factors for the energy corresponding to the nitrogen and carbon excreted, the writer[2] obtained the figures contained in the third column of the following table. Kellner[1] has recomputed the results, using the exact figures for the carbon, nitrogen, and energy content of the flesh of swine which were obtained by Köhler, with the results shown in the last column.

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[1] Zeitschrift für Biologie, vol. 22, p. 63.

[2] Principles of Animal Nutrition, p. 452.

Fasting katabolism of swine—Meissl, Strohmer, and Lorenz.

	Live weight.	Fasting katabolism.	
		Armsby.	Kellner.
	Kilos.	*Therms.*	*Therms.*
Experiment V	140	2.607	2.737
Experiment VI	120	2.291	2.385

Computing Kellner's figures to uniform live weight in proportion to the surface we have:

	Per 50 kilograms.	Per 100 pounds.
	Therms.	*Therms.*
Experiment V	1.377	1.290
Experiment VI	1.333	1.249
Average	1.355	1.270

These figures, according to the principles enunciated in the foregoing pages, may be regarded as representing the available energy required for maintenance. No other direct determinations of this requirement appear to have been made.

In addition to the foregoing, a number of live-weight experiments have been reported.

Dietrich[2] determined the amount of feed required by growing pigs to maintain their live weight at different stages of growth. The trials were made when the animals reached approximately the weights of 50, 100, 150, and 200 pounds, 4 animals being used. The digestibility of the ration fed at the weight of 150 pounds was also determined. The actual average amounts of feed required per day and head were as follows:

Maintenance rations of swine at different ages—Dietrich.

Period.	Average live weight.	Feed required for maintenance.		
		Corn meal.	Middlings.	Skim milk.
	Pounds	*Pounds.*	*Pounds.*	*Pounds.*
I	49.62	0.15	0.15	1.2
II	98.75	.40	.40	1.6
III	151.25	.80	.80	1.6
IV	201.37	.67	1.33	....

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[1] Die Ernährung der Landwirtschaftliche Nutztiere, 5th ed., p. 156.

[2] Wisconsin Experiment Station, 16th Report. 1899, p. 31.

Assuming the composition of the feeding stuffs used to be fairly represented by the averages given in Farmers' Bulletin 22 (revised) and using Jordan's digestion coefficients for middlings, oil meal, and skim milk, and Kellner's coefficients for corn meal, the writer has computed the digestible nutrients contained in the rations consumed with the results shown in the following table. The metabolizable energy of the rations has been computed from the amount of digestible nutrients, using the factors—

	Calories per gram.
Digestible protein	4.1
Digestible nitrogen-free extract	4.2
Digestible crude fiber	3.5
Digestible ether extract	8.8

Computed digestible nutrients and metabolizable energy per day—Dietrich's experiments.

Period.	Digestible nutrients per head.			Metabolizable energy.		
	Protein.	Carbohydrates.	Fat.	Per head.	Per 50 kilograms live weight.	Per 100 pounds live weight.
	Pounds.	*Pounds.*	*Pounds.*	*Therms.*	*Therms.*	*Therms.*
I	0.065	0.241	0.012	0.628	1.069	1.002
II	.126	.561	.028	1.415	1.523	1.427
III	.204	1.038	.050	2.556	2.069	1.939
IV	.205	1.159	.057	2.817	1.885	1.766

Taylor[1] reports quite similar experiments with animals weighing respectively 50, 100, and 150 pounds. Computed in the same manner as the previous experiments, the results are as follows:

Maintenance rations of swine at different ages—Taylor.

Period.	Average live weight.	Feed required for maintenance.		
		Shorts.	Corn meal.	Oil meal.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
I	52.1	0.48	0.24	0.08
III	103.5	1.14	.57	.19
V	157.0	1.20	.60	.20

Computed digestible nutrients and metabolizable energy per day—Taylor's experiments.

Periods.	Digestible nutrients per head.			Metabolizable energy.		
	Protein.	Carbohydrates.	Fat.	Per head.	Per 50 kilograms live weight.	Per 100 pounds live weight.
	Pounds.	*Pounds.*	*Pounds.*	*Therms.*	*Therms.*	*Therms.*
I	0.096	0.434	0.025	1.105	1.821	1.707
III	.288	1.030	.058	2.618	2.730	2.558
V	.240	1.083	.061	2.753	2.174	2.037

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[1] Wisconsin Experiment Station Report, 1901, p. 67.

Carlyle[1] reports the average daily food for maintenance of 12 brood sows for eight weeks after weaning their pigs as follows:

	Pounds.
Average live weight	306
Feed per day and head:	
Corn	1.49
Shorts	1.49
Oil meal	.50
Skim milk	6.90

The computed digestible nutrients and energy of the above ration are:

	Pounds.
Digestible protein	0.654
Digestible carbohydrates	2.307
Digestible fat	.117
Equivalent metabolizable energy:	Therms.
Per head	6.079
Per 50 kilograms live weight	3.077
Per 100 pounds live weight	2.884

In a preliminary report of experiments upon pig feeding, Dietrich[2] estimates the maintenance ration of growing pigs per 100 pounds live weight to be:

	Pounds.
Digestible crude protein	0.10
Digestible carbohydrates	.40
Digestible fat	.04

This ration, using the same factors as before for the metabolizable energy, is equivalent to 1.181 therms per 50 kilograms or 1.107 therms per 100 pounds live weight.

The foregoing results show a wide range in the apparent food requirement for the maintenance of live weight. In general, the lower results seemed to have been reached with the younger animals. This may be due, however, to the fact that, as will be shown in a subsequent paragraph, the maintenance of live weight in a young animal is not necessarily synonymous with the maintenance of its store of potential energy. If we omit the results obtained with the 50-pound animals and also omit Dietrich's results at the Illinois Station, since his experiments seem to have been with comparatively young animals, we find the range of results to be as follows:

	Per 50 kilograms.	Per 100 pounds.
	Therms.	*Therms.*
Minimum	1.523	1.427
Maximum	3.077	2.884
Average	2.243	2.102

On the basis of respiration experiments by Meissl as discussed by Kellner,[3] four rations consisting of not dissimilar feeds showed an approximate average utilization of 74.5 per cent of the metabolizable energy supplied in excess of the fasting katabolism. If we may apply this percentage to the average of the foregoing results regarding maintenance, we may compute the average requirement of available energy to be 2.243×0.745=1.671 therms per 50 kilograms, or 1.566 therms per 100 pounds, a result not differing very widely from the figures computed on a previous page from the results of experiments on the fasting katabolism, but with a very wide range of variation in individual cases.

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[1] Wisconsin Experiment Station, Bulletin 104, p. 31.

[2] Illinois Experiment Station, Circular 126, p. 116.

[3] Die Ernährung der Landwirtschaftliche Nutztiere, 5th ed., p. 157.

THE HORSE.

The maintenance ration of the horse has been the subject of investigation by Zuntz and Hagemann, Wolff, Müntz, and Grandeau and Le Clerc.

ZUNTZ AND HAGEMANN'S INVESTIGATIONS.

Upon the basis of the results regarding the availability of energy for the horse, which have been described on pages 22–25, Zuntz and Hagemann[1] compute the fasting katabolism of the horse by substantially the same method as that employed on pages 34–35 for cattle.

For this purpose, they use those rest experiments on horse III in which the feed consisted of oats, hay, and straw. From the results of the respiration experiments made within the first five hours after feeding, they compute the total energy katabolism per day in the manner indicated on page 22, and from this subtract the energy expended in the digestion of the feed (not including the work of mastication), computed as shown on page 23. The remainder, of course, is the katabolism due to internal work, together with any katabolism resulting from a possible demand for heat to maintain the body temperature. Their results may be tabulated as follows:

Computed fasting katabolism of horse per day and head—Zuntz and Hagemann's experiments.

	Live weight.	Energy katabolism.	Feed.			Work of digestion.	Fasting katabolism.	Fasting katabolism per square centimeter body surface.	Season.
			Oats.	Straw.	Hay.				
	Kilos.	*Therms.*	*Kilos.*	*Kilos.*	*Kilos.*	*Therms.*	*Therms.*	*Gram-calories.*	
Period *a*	428.1	12.541	6	1	7	8.403	4.138	80.7	Winter.
Period *b*	434.1	11.674	6	1	6	7.704	3.970	76.7	Summer.
Period *e*	450.4	12.364	6	1	6	7.704	4.660	87.9	Winter.
Period *f*	449.1	11.783	6	1	4.75	6.830	4.953	93.6	Summer.
Period *i*	440.1	11.893	6	1	6	7.704	4.189	80.2	Winter.
Period *n*	448.2	11.407	4.8	0	5.1	5.672	5.735	108.5	Summer.
Period *c*	442.2	12.450	0	0	10.5	7.340	5.110	97.6	Do.
Period No. 118*c*	434.6	11.021	4.8	0.8	1.88	4.122	6.899	133.3	Winter.

In the experiments with a standard ration of 6 kilograms of oats, 1 of straw, and 6 (or 7) of hay, the average computed fasting katabolism for the three winter periods is 4.329 therms, while in the single summer period it reaches the minimum of 3.970 therms. Zuntz and Hagemann consider that the latter represents approximately the minimum requirement for internal work and regard the higher figures obtained in the winter experiments as indicating a stimulation of the heat production by the low temperature to which the animal was exposed. The notably higher results obtained with the lighter rations they ascribe to a similar cause, viz, that the heat arising from the work of digestion and from the necessary internal work (fasting katabolism) was insufficient to maintain the body temperature. Accordingly, they regard the differences shown in column 8 of the foregoing table as including in these cases not only the minimum necessary for internal work but also an expenditure for heat production. In other words, they consider that the critical temperature (compare p. 71) for the horse is high as compared with that for cattle, and the critical amount of food small (compare p. 73). Earlier experiments[1] upon another horse in which lighter rations were fed confirmed this conclusion.

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[1] Loc. cit., pp. 283–284 and 425–426.

On the average of the 8 most satisfactory experiments out of 12, the estimated total katabolism per day and head was 11.027 therms upon a ration consisting of 3.5 kilograms of oats, 0.5 of straw, and 2.5 of hay. Computed in the same manner as in the foregoing examples, the expenditure of energy in the digestion of this ration is equal to 3.782 therms, which leaves a remainder of 7.244 therms, equivalent to 140.3 gram-calories per square centimeter of surface. This is a higher figure than any of those contained in the foregoing table, although the total katabolism was not notably different. The authors conclude, therefore, that the small amount of heat liberated by the digestive work was compensated for by an increased katabolism of body tissue.

From a balance experiment on the same animal in the respiration apparatus of the Göttingen Experiment Station they also compute[2] the metabolizable energy required for maintenance by subtracting from the total nutrients digested the fat equivalent of the protein and fat gained by the animal. They thus reach a maintenance ration per 500 kilograms, live weight, of 3.265 grams digestible nutrients, equivalent to 12.93 therms. Their final conclusion (loc. cit., p. 426) is that their animal required per head at least 11 therms, or per 500 kilograms live weight 12.10 therms, of heat to maintain his body temperature. In other words, this is the minimum of metabolizable energy which must be supplied in a maintenance ration, since if less be present, even although the ration supplies the requisite amount of available energy, body tissue will still be katabolized for the production of the heat necessary to maintain the body temperature.

Computed to 1,000 pounds live weight in proportion to the two-thirds power of the latter, Zuntz and Hagemann's maintenance ration is:

	Therms.
Available energy for internal work	4.08
Additional required for heat production	7.80
Total metabolizable energy required	11.88

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[1] Landwirtschaftliche Jahrbücher, vol. 18, p. 1; vol. 27, Ergänzungs Band III, pp. 356–257.

[2] Ibid., p. 423–424.

The maintenance requirement as measured by the computed fasting katabolism is notably less than that of cattle. The same criticisms which have been made of Zuntz and Hagemann's conclusions as regards availability are also applicable, of course, to his computation of the maintenance requirement.

WOLFF'S INVESTIGATIONS.

Wolff has also determined by a different method the maintenance ration of the horse in the experiments whose results as regards the available energy of feeds have already been mentioned on page 25. As there noted, the amount of work performed by the horse was adjusted so as to be as nearly as possible in equilibrium with the feed consumed. Wolff's experiments were made with a sweep power arranged to serve also as a dynamometer. The actual measurements of the work performed, except in the later experiments, proved to be too low; but Wolff believes them to be relatively correct, so that the ratio between the work as measured and the additional feed required to produce it may still serve as the basis of computation.

In the experiments of 1877–1886[1] it was found that the work performed in 100 revolutions of the dynamometer required the addition to the ration of 315 grams of digestible nutrients. It is important to note, however, in view of what follows, that this additional digestible material included no digestible crude fiber—that is, that it was practically derived from the grain added in the periods of heavier work. Subtracting from the total digestible nutrients of the ration, therefore, an amount computed on this basis to be equivalent to the work done leaves a remainder representing the nutrients required for maintenance on the virtual assumption that all the work done was performed at the expense of nutrients derived from the grain. The results of these computations are summarized in the following table:

Maintenance rations of horses—Wolff, 1877–1886.

Animal.	Number of experiments.	Total nutrients.	Nutritive ratio.	Live weight.	Number of revolutions.	Equivalent nutrients.	Maintenance ration by difference.
		Grams.		*Kilos.*		*Grams.*	*Grams.*
Horse I	4	6,305.6	1:5.79	521	600	1,890	4,416
Horse II:							
1881–82	7	5,831.1	1:6.64	477	546	1,720	4,111
1882–83	4	6,748.3	1:6.37	486	662	2,085	4,663
1883–84	6	5,920.2	1:7.26	457	567	1,786	4,134
Average	17	6,078.4	1:6.80	473	577	1.818	4,260
Horse III:							
1881–82	6	5,313.8	1:7.16	454	404	1,273	4,041
1882–83	6	6,061.3	1:6.88	469	683	2,152	3.909
1883–84	5	5,734.8	1:7.55	473	580	1,827	3.908
1885	4	5,761.2	1:7.57	473	575	1.811	3,050
Average	21	5,717.8	1:7.29	467	501	1,766	3,952

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[1] Grundlagen für die rationelle Fütterung des Pferdes, 1886, 66–155; Neue Beiträge; Landwirtschaftliche Jahrbücher, vol. 16, Ergänzungs Band III, 1–48.

Computed to 500 kilograms live weight on the basis of what Wolff regards as the normal weights of the animals, the foregoing maintenance rations are:

	Grams.
Horse I	4,143
Horse II	4,260
Horse III	4,167

A series of similar experiments on horse III, weighing 475 kilograms, in 1885–86,[1] computed in substantially the same way, gave results for the maintenance ration agreeing well with those of earlier years, viz:

Maintenance rations of a horse—Wolff, 1885–86.

Period.	Per head.	Per 500 kilograms.
	Grams.	*Grams.*
I	3,934	4,141
II	3.984	4,194
III and V	4,001	4,212
VIIb	4,094	4,310
VIII	4,094	4,310
Average	4,021	4,232

In a succeeding period (IX), however, in which hay alone was fed, a decidedly higher result was obtained, viz, 4,357 grams per head, or 4,586 grams per 500 kilograms.

In these earlier experiments, in accordance with the views then prevalent, Wolff regarded the so-called nutrients as of equal value whatever their source. The experiment with hay, just mentioned, however, suggested that such was not the case and this suspicion was confirmed by later investigations which clearly showed the superiority of the digestible matter of grain over that of hay. This superiority was not apparent in the earlier experiments because the proportions of grain and coarse fodder were not widely different in the several experiments, the coarse fodder furnishing on the average fully one-half of the dry matter fed.

This difference, suggested by the experiment on hay, was demonstrated by a comparison by Wolff[2] of his own results with those obtained by Grandeau and Le Clerc[3] in experiments upon two cab horses receiving only a small amount of walking exercise. The ration used by the latter experimenters consisted of about 75 per cent of grain as against less than 50 per cent in Wolff's experiments, and from it Wolff computes an average maintenance ration per 500 kilograms of 3,626 grams of digestible nutrients as compared with the 4,000 to 4,200 grams of the foregoing table.

Direct experiments by Wolff[4] likewise show that the digestible nutrients of concentrated feed (oats) are more valuable for work production than those of coarse feed (hay). The experiments were made in the manner already described, the draft being uniformly 60 kilograms. Although the measurements of the work actually done are probably incorrect, it may be assumed to have been substantially proportional to the number of revolutions of the dynamometer. A ration of 3 kilograms of hay and 5.5 kilograms of oats served as the basal ration, to which was added on the one hand 4 kilograms of hay and on the other 1½ kilograms of oats. The nutrients digested in each case and the equivalent amounts of work secured were:

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[1] Landwirtschaftliche Jahrbücher, vol. 13, Ergänzungs Band III, p. 32.

[2] Ibid., pp. 73–81.

[3] L'Alimentation du Cheval de Trait, 1883, II, 86 and 131.

[4] Loc. cit., pp. 84–95.

Nutrients equivalent to work—Wolff, 1886–87.

Period.	Ration.	Digested.					Equivalent work.
		Protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Total (fat × 2.4).	
		Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Revolutions.*
I–III	7 kilograms hay, 5.5 kilograms oats	822.58	816.68	3,889.64	186.72	5,973.62	750
V	3 kilograms hay, 5.5 kilograms oats	626.46	422.74	3,068.78	184.78	4,561.13	350
	4 kilograms hay	196.12	393.94	821.18	1.94	1,412.49	400
	Per 100 revolutions					353.12	
VI	3 kilograms hay, 7 kilograms oats	754.52	355.24	3,719.24	252.17	5,434.21	700
V	3 kilograms hay, 5.5 kilograms oats	626.46	393.94	3,068.46	184.78	4,561.13	350
	1.5 kilograms oats	128.06	−67.50	650.78	67.39	873.08	350
	Per 100 revolutions					249.45	

The relative value of the digested matter of hay and of oats for work production in these trials was thus approximately as 5 : 7.

The digestible nutrients added to the ration by the oats in period VI included no crude fiber, and, as the table shows, 249 grams of these fiber-free nutrients were found equivalent to 100 revolutions of the dynamometer with a draft of 60 kilograms, which is practically equivalent to the 315 grams per 100 revolutions with 76 kilograms draft found in the earlier experiments (p. 57) in which also, as was noted, the additional nutrients were practically fiber-free. Of the digestible nutrients added to the ration in the form of hay in period I–III, on the other hand, over one-fourth consisted of crude fiber, and in this case 353 grams were found to be equivalent to 100 revolutions of the dynamometer. If, however, the digestible crude fiber be omitted in this case, it appears that the fiber-free nutrients of the hay were practically equivalent to those of the oats, 255 grams being required for each 100 revolutions.

As noted previously, Wolff recomputed his experiments on the assumption that the crude fiber was valueless, and obtained results expressed in terms of fiber-free nutrients which were consistent among themselves and agreed with those obtained by Grandeau. The following table contains a summary of the results obtained for the maintenance ration expressed both in terms of total nutrients (including digestible crude fiber) and of fiber-free nutrients:

Nutrients for maintenance per 500 kilograms live weight—Wolff.

Experiments.	Including fiber.	Fiber-free.
	Grams.	*Grams.*
Experiments of 1881–1885:		
Horse I	4,143	3,378
Horse II	4,260	3,282
Horse III	4,167	3,306
Average	4,190	3,322
Experiments of 1885–86—Horse III:		
Period I	4,141	3,442
Period II	4,194	3,353
Period III and V	4,212	3,413
Period VII	4,310	3,549
Period VIII	4,310	3,490
Period IX	[4,586]	3,335
Average	[1] 4,232	3,430

[1] Omitting period IX.

Nutrients for maintenance per 500 kilograms live weight—Wolff—Continued.

Experiments.	Including fiber.	Fiber-free.
Grandeau's experiments:	*Grams.*	*Grams.*
Horse II	3,636	3,324
Horse III	3,617	3,328
Average	3.626	3.326
Experiments of 1886–87:		
Period I–III	4,202	3,342
Period IV	4,150	3,429
Period V	3,792	3,329
Period VI	3,738	3.364
Average	3.971	3,366

The figures inclusive of the crude fiber, as computed by Wolff, evidently correspond approximately with the amounts of metabolizable energy contained in various mixed rations which were sufficient for maintenance. In the earlier experiments, and in those later ones in which approximately equal proportions of hay and grain were consumed, the amount is approximately 4,200 grams per 500 kilograms live weight, which, using Zuntz and Hagemann's factor of 3.96 calories per gram, is equal to 16,632 calories. In the later experiments, in which a larger proportion of grain was fed, the total nutrients required for maintenance ranged from 3,600 to 3,700 grams, equivalent to from 14,257 to 14,652 calories. In other words, the amount of metabolizable energy necessary for maintenance varied with the proportion of coarse fodder present, as would be expected from the results with cattle recorded on previous pages.

The maintenance ration in terms of metabolizable energy, as thus computed, is comparable with that estimated by Zuntz and Hagemann, in the manner explained on pages 55–56, from the total heat production of the animal. That Wolff's results are higher is probably due to the relatively larger proportion of crude fiber in his maintenance rations, since, as shown on page 57, the work is assumed by Wolff's method of calculation to have been done at the expense of the nutrients of the grain, and consequently the remaining portion of the ration, which is regarded as the maintenance portion, was relatively poorer in grain and richer in coarse fodder.

Zuntz and Hagemann[1] attempt to estimate the difference due to the latter fact. They average 31 of Wolff's experiments, divided into two groups, viz, those on light and on heavy work, correcting the actual amount of work done for the loss of live weight and likewise for what they regard as Wolff's error in his estimate of the energy expended in locomotion. They also correct Wolff's estimate of the energy of the digested matter by the use of the factor 3.96 calories per gram instead of 4.1 calories per gram. Their comparison of the two groups gives them by difference 31 per cent as the proportion of the available energy of the digested nutrients which was recovered in the form of work, a percentage corresponding very closely to that found for the work of draft in their experiments, viz, 31.4. Upon this basis, they compute in each group the amount of nutrients required for the total work done and by subtraction the total digestible nutrients required for maintenance.

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[1] Loc. cit., pp. 420–424; Principles of Animal Nutrition, p. 546.

Their results for an animal weighing approximately 500 kilograms are as follows, the equivalent metabolizable energy being obtained by the use of Zuntz and Hagemann's factor of 3.96 calories per gram. The average does not differ materially from that computed directly from Wolff's later experiments.

	Total digestible nutrients.	Equivalent metabolizable energy.
	Grams.	*Therms.*
Periods of light work	3,776	14.95
Periods of heavy work	3,763	14.90
Average	3,770	14.93

This result they compare with that obtained by them in a balance experiment with a respiration apparatus from which, as noted on page 56, they compute a maintenance ration of 12.93 therms. Their ration, however, contained notably less crude fiber than did Wolff's rations, the differences being as shown in the following table, which includes also the equivalent digestive work, estimated by Zuntz and Hagemann at 2.65 calories per gram:

	Difference in crude fiber fed.	Equivalent digestive work.
	Grams.	*Therms.*
Periods of light work	974	2.58
Periods of heavy work	956	2.53
Average	965	2.56

Subtracting this amount from the average computed from Wolff's experiments leaves a remainder of 12.37 therms as the metabolizable energy which would have been necessary for maintenance had Wolff's rations contained no more crude fiber than Zuntz and Hagemann's.

Wolff's experiments afford no data for computing in terms of available energy the maintenance requirement in the sense in which this term is used by Zuntz and Hagemann and in the discussion of the maintenance requirements of cattle, on pages 33 to 35, viz, as equivalent to the necessary demand for internal work. Even if we follow Wolff in regarding the energy of the fiber-free nutrients as an approximate expression of the available energy, his computation of the fiber-free nutrients required for maintenance simply shows the amount of available energy (in this sense) present in a maintenance ration, but gives no indication of how much of this may have been consumed in simple heat production.

MÜNTZ'S EXPERIMENTS.

Müntz,[1] in 1878–79, attempted to determine the maintenance ration of the horse by a different method, viz, by starting with an insufficient ration and gradually increasing it until an equilibrium between food and live weight was secured. His experiments were made upon horses of the Paris Omnibus Co. whose work ration was known from previous experiments. Upon one-third of their regular working ration four horses lost in from one to one and a half months an average of 1.02 pounds per day and head. The ration was then increased to one-half of the work ration. Upon this nine horses, including the four used in the previous experiments, gained on the average 1.08 pounds per day and head. Upon decreasing the ration to five-twelfths of the work ration, six other horses gained 0.46 pound per day and head. The amount of total organic matter consumed by the animals is recorded. Estimating from this the total digestible nutrients and computing the metabolizable energy of the latter at the rate of 3.96 calories per gram, the last two rations afforded the following results:

Metabolizable energy in rations of horses—Müntz.

	Average gain in weight per day.	Average live weight.	Digestible nutrients.	Metabolizable energy.	
				Per head.	Per 1,000 pounds live weight.
	Kilos.	*Kilos.*	*Grams.*	*Therms.*	*Therms.*
One half of work ration	+0.49	545	4,102	16.24	14.37
Five-twelfths of work ration	+0.19	523	3,417	13.53	12.31

GRANDEAU AND LE CLERC'S RESULTS.

Grandeau and Le Clerc,[2] in addition to the experiments recorded in connection with Wolff's results, fed five cab horses a daily ration of 8 kilograms of hay during a total of 14 periods of a month each (1 to 5 periods for each animal), during each of which the digestibility of the ration was determined. The animals had only a small amount of walking exercise daily. The following are the results of the several periods:

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[1] Annales de l'Institut National Agronomique, Tome 3. 1878–79.

[2] L'Alimentation du Cheval de Trait, 1883, III.

Metabolizable energy in rations of horses—Grandeau and Le Clerc.

	Total digestible nutrients.[1]	Equivalent metabolizable energy.	Average daily gain or loss of weight.	Average live weight.
Horse 30845 (No. 1):	*Grams.*	*Therms.*	*Kilos.*	*Kilos.*
January, 1884	2,895.3	11.467	−0.19	394.9
April, 1884	2,351.9	9.315	+0.47	379.2
August, 1884	2,795.5	11.071	+0.03	365.0
September, 1884	2,927.8	11.595	[2]−0.03	366.3
October, 1884	2,897.1	11.473	[2]0.00	366.0
Average	2,773.5	10.983	+0.06	374.3
Horse 29475 (No. 2):				
November, 1883	3,041.4	12.045	+0.59	423.6
Horse 29406 (No. 2):				
May, 1884	2,470.2	9.784	+0.42	404.0
June, 1884	2,909.5	11.523	+0.13	407.1
July, 1884	2,692.8	10.663	+0.18	410.6
Average	2,690.8	10.656	+0.24	407.2
Horse 29407 (No. 3):				
December, 1883	3,062.1	12.128	−0.05	413.9
Horse 26925 (No. 3):				
March, 1884	2,726.8	10.799	+0.82	419.0
June, 1884	2,644.5	10.473	+0.27	384.3
July, 1884	2,719.4	10.770	0.00	387.7
August, 1884	2,837.9	11.238	−0.01	388.4
Average	2,732.2	10.820	+0.27	394.9

[1] Including fat ×2.4.

[2] Omitting last day of each month.

On the average of all the periods, the results per day and head were as follows:

Total digestible nutrients (fat×2.4)	grams	2,783.7
Equivalent metabolizable energy, at 3.96 calories per gram	therms	11.03
Daily gain in weight	kilograms	0.19
Average live weight	do	393.6

The foregoing ration, which was apparently somewhat more than a maintenance ration, is equivalent to 12.12 therms of metabolizable energy per 1,000 pounds live weight. This is materially less than was obtained in Wolff's experiments and about the same as that found by Zuntz and Hagemann for rations containing much grain.

TRUE MAINTENANCE AND LIVE-WEIGHT MAINTENANCE.

The maintenance of an animal in the strict scientific sense signifies the preservation of the store of matter and of potential energy contained in the body, and only a ration which effects this is really a maintenance ration. As has appeared in the foregoing pages, however, much of our recorded information regarding the maintenance ration is derived from experiments in which the sufficiency of the ration was judged of from its effect in maintaining the live weight of the animal. In experiments on mature animals extending over a considerable period of time, it is unlikely that any gross error is involved, especially if determinations of the nitrogen balance show the protein supply to be adequate. In short periods, on the other hand, and especially in experiments upon young animals, the live weight is a notoriously untrustworthy guide. The general reasons for this are familiar, but in young animals another very important factor enters into consideration. As is well known, the tendency to growth is one of the most marked characteristics of young animals. Waters[1] has shown that this impulse to increase of tissue is so marked that it may apparently take precedence over the demand for maintenance, so that an animal may continue to increase in size of skeleton for a considerable time even on a submaintenance ration.

Some 15 immature cattle were fed for considerable periods on rations just sufficient to maintain their live weight. Under these conditions the animals continued to grow in height, in depth of chest, and length of head. At the same time, however, there was an evident falling off in the amount of fat tissue, both as judged by the eye and as shown by the appearance and by the chemical composition of the carcass. Histological studies, too, showed a reduction in the size of the fat cells, and analysis of the adipose tissue showed a lower fat and higher water and protein content than in check animals. What occurred was evidently a consumption of body fat to supply energy, while at the same time an approximately equal weight of protein tissue was produced which, on account of the relatively low energy value of protein and of the relatively large amount of water accompanying it, represented a much smaller quantity of energy than did the fat tissue which disappeared. In other words, the rations were not really, but only apparently maintenance rations. It is perhaps hardly correct to say that in these experiments growth was maintained at the expense of the fat of the tissues. A more exact statement of the case would be that the increase of protein tissue and water masked the loss of fat. Presumably this effect would be less marked in more mature animals, in which the true maintenance and live-weight maintenance would doubtless approach each other closely when measured over long periods.

FACTORS AFFECTING THE ENERGY REQUIREMENT.

The results of the experiments upon farm animals reported on previous pages render it evident that the actual maintenance requirement, even when computed to a uniform weight or size, is more or less variable. For example, in the case of cattle, for which the most extensive and accurate data are available, the range of the energy requirement per day and 1,000 pounds live weight for thin animals in those experiments which are apparently the most accurate is 4.9 to 7.3 therms available energy or 8.5 to 12.8 therms metabolizable energy. Several causes may be responsible for these variations.

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[1] Society for the Promotion of Agricultural Science, Proceedings of 29th Annual Meeting, p. 71.

MUSCULAR ACTIVITY.

In considering the factors of the fasting katabolism (p. 9), attention was called to the large share which the muscles, and especially the voluntary muscles, have in the heat production of the animal. Even in a state of the most complete rest possible, a very considerable share of the total katabolism takes place in these tissues, due, presumably, to the state of constant slight tension or "tonus" of the living muscle.

MINOR MUSCULAR MOTIONS.

It is rarely the case, however, that an animal, even when at rest in the ordinary sense, does not execute more or less motions of various parts of the body, all of which involve an expenditure of energy, and even apparently insignificant movements may materially increase the amount of metabolism.

Zuntz and Hagemann,[1] for example, report a respiration experiment upon a horse in which the uneasiness caused by the presence of a few flies in the chamber of the apparatus caused an increase of 10 per cent in the metabolism. Johansson[2] compared the excretion of carbon dioxid by a fasting man when simply lying in bed (awake) with that occurring when all the muscles were as perfectly relaxed as possible. The results per hour were:

Excretion of CO_2 by fasting man.

	Grams.
Lying in bed	24.94
Complete muscular relaxation	20.72

Benedict and Carpenter[3] have compared the metabolism of men during sleep with that of the same subjects lying quietly in bed immediately after waking. In the three cases which they regard as strictly comparable the increase in the heat production during the waking period ranged from 5.8 to 15.2 per cent, averaging 11.4 per cent.

If, then, these comparatively insignificant movements have such a striking effect upon the metabolism, it is evident that the amount of muscular activity must be an important factor in determining the relative maintenance requirements of two animals even though their minimum physiological requirements may be identical. In experiments of any considerable duration on normal animals, it is impossible to avoid more or less expenditure of energy in this incidental muscular work, while it is often a matter of difficulty to make the different periods of an experiment comparable in this respect.

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[1] Landwirtschaftliche Jahrbücher, vol. 23, p. 161.

[2] Skandinavisches Archiv für Physiologie, vol. 8, p. 85.

[3] Carnegie Institution of Washington, Publication 126, p. 241.

LYING AND STANDING.

Furthermore, considerable muscular exertion is involved during the waking hours in maintaining the relative position of the different members of the body. This is notably true of the effort of standing. In experiments by Armsby and Fries[1] the heat radiated per minute by a steer while standing was found largely to exceed that given off while lying, the excess in 25 experiments ranging from 28.3 to 64.5 per cent, although there were indications that the amount of feed consumed was also a factor.

On the other hand Dahm,[2] working in Zuntz's laboratory and by his methods, found an increase of only 8 per cent in the respiratory excretion of CO_2 by a young bull when standing as compared with that when lying, but Zuntz[3] himself in earlier experiments on a dog observed differences similar to those found by Armsby and Fries for cattle, the average oxygen consumption per minute being while lying 174.3 c. c. and while standing 245.6 c. c., or an increase of 41 per cent. Benedict[4] observed an increase of from 13.3 to 18.8 per cent, or an average of 16.5 per cent, in the heat production of man when standing as compared with that observed when sitting quietly in a chair.

It is clear, then, that of two animals, one of which lies down for 12 hours and the other for 8 hours out of the 24, the former will, other things being equal, require less energy for maintenance. In the results regarding the maintenance ration thus far reported, with the exception of the Pennsylvania experiments, this factor has not been taken into account.

INDIVIDUALITY.

It appears quite probable that those differences between the maintenance requirements of different animals which are ascribed somewhat vaguely to "individuality" are due to a large extent to varying amounts of muscular activity. In general, the nervous, restless animal will have a higher maintenance requirement than the quiet, phlegmatic one. Thus the table on page 40 shows that Armsby and

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[1] Bureau of Animal Industry, Bulletins 51, 74, 101, and 128.

[2] Biochemische Zeitschrift, vol. 28, p. 494.

[3] Archiv für die gesammte Physiologie des Menschen und der Thiere (Pflüger), vol. 68, p. 191.

[4] Loc. cit., p. 244.

Fries's steer A had in every case a materially lower maintenance requirement than steer B, even when the results were corrected to an equal number of hours standing per day. Computed per 1,000 pounds live weight and corrected to 12 hours standing, the results for available energy were as follows:

Available energy required for maintenance—Armsby and Fries.

	Steer A.	Steer B.
	Therms.	*Therms.*
1905	6.23	7.06
1906	5.70	6.38
1907	4.86	6.50

Steer B was an animal of rather pronounced dairy type and of a nervous disposition, and in all probability his higher maintenance requirement is to be ascribed to this fact. There can be little doubt that temperament is an important factor in determining the maintenance requirement and that there may be a considerable range of individual differences in this respect.

Similarly, any conditions tending to affect the degree of muscular activity will also tend to affect the maintenance requirement. The steer confined in a stall, for example, is likely to take less muscular exercise and therefore to require a smaller amount for maintenance than one simply confined to a pen or an open yard. The animal comfortably bedded and thereby induced to spend much of his time in lying down will consume a smaller portion of his feed for maintenance than one kept under less comfortable conditions. Any sort of excitement is likely to cause increased muscular activity and correspondingly increased consumption of food for maintenance.

CONDITION.

The condition of an animal—that is, the amount of adipose tissue carried—seems to influence the maintenance ration, at least in the case of cattle. This point was first investigated by Kellner.[1] His average result for three fat cattle, as shown in the table on page 43, is considerably higher when computed to the same live weight—that is, per unit of surface—than that for the seven lean animals, viz:

Unfattened___ 10.87 therms metabolizable energy per 1,000 pounds live weight.
Fattened_____ 15.05 therms metabolizable energy per 1,000 pounds live weight.

Only one animal, however, was common to the two groups, viz, steer B, the results on which were excluded from the average of the unfattened animals on the ground that it was abnormally high, since the animal never lay down during the experiments. Curiously enough, this animal showed the lowest maintenance ration of the three fattened animals and, moreover, one which is distinctly less per unit of computed surface than in the unfattened state, viz:

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[1] Die Landwirtschlichen Versuchs-Stationen, vol. 50, p. 245; vol. 53, p. 14.

Unfattened.... 14.72 therms metabolizable energy per 1,000 pounds live weight.
Fattened...... 13.86 therms metabolizable energy per 1,000 pounds live weight.

No other respiration experiments upon the relative maintenance requirements of fattened and unfattened animals are on record. Evvard's live-weight results, however, as given in the table on page 47, appear to confirm Kellner's conclusion that the relative maintenance ration of fattened animals is greater than that of the same animals unfattened.

One obvious reason why the maintenance requirement should be greater in the former case is the presumably greater muscular effort expended in standing, due to the greater weight to be supported. Zuntz and Hagemann in experiments upon the horse carrying weight on its back found that this increase was proportional to the amount of weight added. The increase indicated by Kellner's averages, however, is greater than would be computed on this assumption, and the same is true of Evvard's fat animals, the difference becoming greater as the animals become fatter.

AGE.

The energy requirement of a young animal is naturally smaller per head than that of an older animal on account of the difference in size. Whether there is any difference in the relative requirements—that is, in the requirement computed to uniform weight or surface—is not altogether clear, few specific results on farm animals being on record. Evvard's results on yearlings, page 46, are somewhat higher than most of the results which have been obtained with mature cattle, although, of course, these figures do not refer to the same individuals at different ages. Armsby and Fries,[1] in a series of respiration calorimeter experiments upon the same two animals in three successive years, observed a progressive decrease in the maintenance requirement of yearlings, 2-year-olds, and 3-year-olds when corrected to a uniform number of hours standing and computed to equal external surface (that is, in proportion to the two-thirds power of the weight).

Somewhat extensive data are on record regarding the metabolism of man at different ages. A summary and discussion of these by Tigerstedt[2] seem to show clearly that, leaving out of account infants and very aged persons, the metabolism per unit of surface diminishes from youth to maturity. In view of the slow development of man, these results are comparable to such as might be obtained during the first 6 to 12 months of the life of ordinary domestic animals and for these ages we have few satisfactory determinations of the maintenance requirement. The results upon swine cited on previous pages seem, it is true, to indicate the contrary relation, viz, a lower relative maintenance requirement for young animals. These results, however, are based upon live-weight experiments and, as already noted, are possibly lower than the true maintenance ration.

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[1] Bureau of Animal Industry, Bulletin 128, p. 55.

[2] Nagel's Handbuch der Physiologie des Menschen, I, 469.

If it be true that the maintenance rations of young animals are relatively greater than those of older ones, we may fairly presume it to be due to a considerable extent to the greater amount of muscular activity usually exhibited by young animals.

EXTERNAL TEMPERATURE.

Farm animals belong to that general class known as warm-blooded or homoiothermic animals, whose bodies maintain a nearly constant temperature during health, regardless of that of their surroundings unless the latter be extreme, in which case death soon results.

REGULATION OF BODY TEMPERATURE.

Obviously, the regulating mechanism which maintains a constant temperature in spite of variations in the heat production of the body and in the temperature of its surroundings must be very efficient and very exactly adjusted. The regulation is effected in general in two ways, which may be called, respectively, physical and chemical regulation.

The heat of an animal escapes from the surface of tne body chiefly through the skin, but to some extent also through the air passages, being removed both by conduction, by radiation, and by the evaporation of water. A rise of external temperature tends to check the outflow of heat exactly as it would in the case of an inanimate body. This tendency is compensated by a nervous reflex, which allows the capillary blood vessels of the skin to enlarge so that more blood flows through them, thus tending to raise the temperature of the surface and increase the outflow of heat. This phenomenon is readily observed in the flush which follows exposure to high temperatures. This method of regulation is analogous to opening the windows of a room to cool it. If the external temperature continues to rise, perspiration appears, or in the case of animals that have no sweat glands, like the dog, a peculiar form of breathing sets in, and relatively large amounts of water are evaporated from the skin or from the tongue and the interior of the mouth and throat. In this way large quantities of heat are carried off as the latent heat of evaporation of water, somewhat as an overheated room may be cooled by sprinkling the floor. When the external temperature falls again, the process is reversed. Sensible perspiration decreases and the blood is diverted from the capillaries of the skin to the internal capillaries. If this happens too quickly, it may even lead to congestion of the latter. The process is analogous to the closing of the windows of a room as the weather grows colder.

There is evidently a limit to this method of regulation. If the windows are entirely closed nothing more can be effected in this manner, and if the weather continues to grow colder the fire in the room must be increased. So if the external demand for heat becomes so great as to exceed the limits of adjustment in the body more fuel material is katabolized—that is, more heat is produced. This was first demonstrated by Carl Voit, who obtained the following results for the excretion of carbon dioxid by a man at various temperatures:

Influence of external temperature on metabolism of man—Carl Voit.

Temperature.	Carbon dioxid.	Urinary nitrogen.	Temperature.	Carbon dioxid.	Urinary nitrogen.
° *C.*	*Grams.*	*Grams.*	° *C.*	*Grams.*	*Grams.*
4.4	210.7	4.23	23.7	164.8	3.40
6.5	206.0	4.05	24.2	166.5	3.34
9.0	192.0	4.20	26.7	160.0	3.97
14.3	155.1	3.81	30.0	170.6	....
16.2	158.3	4.00			

Later and more comprehensive experiments with animals by Rubner have given corresponding results. Thus with two guinea pigs the following figures were obtained in 24-hour experiments:[1]

Influence of external temperature on metabolism—Rubner.

Mature animal.			Young animal.		
Temperature of air.	Temperature of animal.	CO^2 per kilogram and hour.	Temperature of air.	Temperature of animal.	CO^2 per kilogram and hour.
° *C.*	° *C.*	*Grams.*	° *C.*	° *C.*	*Grams.*
0	37.0	2.905	0	38.7	4.500
11.1	37.2	2.151	10	38.6	3.433
20.8	37.4	1.766	20	38.6	2.283
25.7	37.0	1.540	30	38.7	1.778
30.3	37.7	1.317	35	39.2	2.266
34.9	38.2	1.273			
40.0	39.5	1.454			

A later experiment by Rubner[2] upon a dog, in which the heat production was measured by a calorimeter, gave the following results:

Temperature of air.	Heat production per kilogram.
° *C.*	*Calories.*
7.6	83.5
15.0	63.0
20.0	53.5
25.0	54.2
30.0	56.2

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[1] Biologische Gesetze, p. 13.

[2] Archiv für Hygiene, vol. 11, p. 285.

CRITICAL TEMPERATURE.

It is clear from the foregoing results that when the external temperature falls below a certain limit the heat production of the animal shows a marked increase. This point at which the physical regulation gives way to or begins to be supplemented by the chemical regulation has been called the "critical temperature" for the animal. Above this temperature the radiating capacity of the body surface is varied to meet the varying conditions; below it this method of regulation is largely exhausted, and therefore the heat production is varied to suit the needs. This latter so-called chemical regulation is probably effected largely in the muscles, either by visible motion or by increase in the muscular tonus, either of which involves an increased heat production. This has been clearly shown to be true of man and probably applies also to other animals. Above the critical temperature there appears to be a slight increase in the heat production with rising temperature, probably due to the additional energy required for the various processes of physical regulation.

Any conditions tending to facilitate the escape of heat from the body would obviously act like a fall of temperature. Wind, for example, by removing the layer of partially warmed air next to the skin, tends to remove the heat more rapidly from the body, so that the cold is felt more severely on a windy day, while, on the other hand, the effect of a high temperature is modified by wind. A high percentage humidity of the air on a warm day hinders the removal of heat by evaporation, so that a moist heat is more trying than a dry heat. Cold, moist air, on the other hand, facilitates the escape of heat from the body by increasing the conducting power of the clothing, hair, or fur, so that a damp cold is more severe than a dry cold. The direct rays of the sun may impart a considerable amount of heat to the body, thus moderating the effect of low temperature and, on the other hand, increasing that of high temperature.

FEED CONSUMPTION A SOURCE OF HEAT.

For the sake of simplicity, the foregoing paragraphs have dealt especially with the case of the fasting animal, neglecting one important source of heat, viz, the consumption of feed. As was shown on pages 19–28, the latter results in increasing the katabolism of the body, and whether this be considered the result of the work of digestion or simply designated as specific dynamic effect, the fact is established beyond question. This heat, however, once generated, while unavailable for the physiological processes of the body is just as useful as external heat for keeping it warm. In other words, the consumption of feed will tend to have the same effect as a rise of external temperature. This being the case, it is clear that at temperatures considerably below the critical temperature, all the metabolizable energy of the feed will be of use to the body. Part of it will be available for physiological uses as already explained, but the remainder, while not available in this sense will nevertheless be of use as a source of heat.

ISODYNAMIC REPLACEMENT.

It was upon his earlier experiments (published in 1883) made under substantially the conditions just indicated that Rubner based his famous law of isodynamic replacement of nutrients which has played a large part in the discussion of nutrition problems. This law may be briefly stated as follows: *In amounts less than a maintenance ration the nutrients replace each other or body tissue in inverse proportion to their metabolizable energy.* The quantities which thus replace each other are accordingly said to be isodynamic. It need scarcely be pointed out that the minimum of protein required for the maintenance of the nitrogenous tissues is not included under this law. Rubner was careful to limit the law to small amounts of food. In his earlier publications he stated that it holds only below the maintenance ration; somewhat later he asserted[1] that it obtains up to an excess of about 50 per cent over the maintenance requirement.

These results of Rubner's have passed into the literature of physiology and are still largely interpreted as representing the relative values of nutrients, while Rubner's factors for the metabolizable energy of nutrients have been extensively used in computing the energy values not only of human dietaries but of stock rations as well. Historically, Rubner's earlier investigations mark an epoch in the science of nutrition. While similar views had previously been advanced by others, Rubner appears to have been the first to investigate the subject experimentally. The conception that the replacement values of the nutrients could be measured by the relative contributions of energy which they make to the activities of the body was a contribution of the first order to the study of nutrition problems, but the exact form given it in these earlier experiments proves to have been but a partial expression of the truth, as Rubner's own later experiment, as well as those of others, have fully demonstrated. (Compare pp. 26–28.)

RELATION OF MAINTENANCE RATION TO CRITICAL TEMPERATURE.

When its surroundings are above the critical temperature, the animal is producing a surplus of heat as a consequence of its necessary physiological activities and disposes of it by the processes of physical regulation already described. The heat produced is then in a sense an excretum, and under these conditions obviously the external temperature does not materially affect the maintenance ration. The latter, as already shown, is measured by the amount of available energy necessary to support the vital processes, i. e., by the total fasting katabolism.

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[1] Biologische Gesetze, p. 20.

Below the critical temperature, however, the conditions are different. At relatively low temperatures all the metabolizable energy of the feed is used directly or indirectly to keep the animal warm, and as the external temperature falls, either more feed must be given or more tissue burned to supply the additional heat required to maintain the body temperature.

FEED CONSUMPTION LOWERS THE CRITICAL TEMPERATURE.

Since feed consumption is itself a source of heat, the animal consuming feed can, other things being equal, withstand a lower temperature than when fasting, and the larger the amount of feed consumed the lower is the corresponding temperature. The matter may also be put in the reverse way. For any particular (low) temperature there is a certain amount of feed the digestion and assimilation of which will yield an amount of heat sufficient to supplement that derived from the fasting katabolism, so as to just maintain the body temperature. This particular external temperature, then, is the critical temperature for that amount and kind of feed, and, conversely, that particular ration may be called the critical amount of feed for the particular external temperature.

CRITICAL TEMPERATURE FOR FARM ANIMALS.

The critical temperature for farm animals has not been definitely determined. In the case of cattle and probably of sheep, however, it is apparently rather low for animals consuming an ordinary ration. Thus Armsby and Fries have found that at about 18° C. the ration of cattle can be reduced considerably below the maintenance requirement without any evidence of increased oxidation of tissue for the sake of heat production. In the case of fattening animals consuming heavy rations and therefore producing a large amount of heat as a result of digestive work, the critical temperature would be still lower and experiments upon such animals have shown that they may be exposed to comparatively low temperatures, as in an open shed or yard, without causing them to oxidize any more food material. As already stated (p. 56) the critical temperature for the horse appears to be relatively higher.

THE PROTEIN REQUIREMENT FOR MAINTENANCE.

PROTEIN KATABOLIZED DURING FASTING.[1]

It has already been shown on pages 11–12 that in the previously well-nourished fasting animal the katabolism of protein supplies but a small part of the total energy required for the support of the vital functions. As a preliminary to the consideration of the protein requirement, however, some further consideration of the protein katabolism during fasting is desirable.

INFLUENCE OF PREVIOUS FEED.

The classic experiments of Carl Voit upon fasting dogs showed that while the protein katabolism in the early days of fasting may vary widely according to the previous feed, it soon falls to a comparatively low level which is approximately the same for the individual animal whatever its amount upon the initial days. This behavior is well illustrated by the following results, all upon the same animal, which have been fully confirmed by numerous subsequent experiments.[2]

Protein katabolism of fasting dog—Voit.

	2,500 grams meat.	1,800 grams meat; 250 grams fat.	1,500 grams meat.	1,500 grams meat.	Bread.
Urinary nitrogen[3] per day:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Last day of feeding	84.4	60.7	51.7	51.7	11.5
First day of fasting	28.1	17.5	13.9	12.4	9.1
Second day of fasting	11.6	10.9	8.5	8.7	7.3
Third day of fasting	8.9	7.8	8.2	7.3	7.0
Fourth day of fasting	8.1	6.9	7.0	7.0	6.2
Fifth day of fasting	5.7	5.9	6.6	6.9	5.9
Sixth day of fasting	6.2	6.0	6.1	6.0	6.1
Seventh day of fasting	5.8	5.6	5.6	6.0	....
Eighth day of fasting	4.7	....	6.0	5.6	....
Ninth day of fasting	....	....	....	5.6	....
Tenth day of fasting	....	....	....	5.3	....

FASTING KATABOLISM VARIABLE.

It is not true, however, as is sometimes loosely stated, that the protein katabolism of a fasting animal is a constant quantity. On the contrary, in the presence of an adequate amount of body fat, its amount tends to diminish with the progress of fasting. This fact appears more or less clearly in the foregoing experiments, while in later ones it is quite marked. For example, in the experiments by

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[1] Compare references on p. 8.

[2] Zeitschrift für Biologie, vol. 2, p. 307.

[3] Computed from Voit's figures for urea. In earlier experiments upon the protein metabolism the urea in the urine, as determined by Liebig's titration method, was commonly taken as the measure of protein katabolism. Later experience has shown that these results are not strictly accurate, but the amount of urea under such circumstances is so nearly proportional to the total urinary nitrogen that the results as given above are entirely adequate as an illustration of the point under discussion.

Benedict, cited on page 15 in illustration of the relative constancy of the energy katabolism, the total protein katabolism showed a distinct falling off, and the same is true in less degree when computed per kilogram weight. The total urinary nitrogen upon the several days of the experiment was:

Protein katabolism of fasting man—Benedict.

Days.	Urinary nitrogen.		Days.	Urinary nitrogen.	
	Total.	Per kilogram weight.		Total.	Per kilogram weight.
	Grams.	*Gram.*		*Grams.*	*Gram.*
1	12.24	0.206	5	10.87	0.191
2	12.45	.211	6	10.74	.190
3	13.02	.223	7	10.13	.181
4	11.63	.202			

E. and O. Freund[1] determined the daily nitrogen excretion of Succi, a professional faster, with the following results:

Protein katabolism of fasting man—E. and O. Freund.

Days.	Nitrogen.	Days.	Nitrogen.	Days.	Nitrogen.
	Grams.		*Grams.*		*Grams.*
1	17.0	8	9.74	15	5.06
2	11.2	9	10.05	16	4.32
3	10.55	10	7.12	17	5.4
4	10.8	11	6.23	18	3.6
5	11.19	12	6.84	19	5.7
6	11.01	13	5.14	20	3.3
7	8.79	14	4.66	21	2.82

A similar phenomenon was observed by Michaud in experiments on the relative value of proteins described on a subsequent page. A dog, after 44 days abstinence from protein (16 days without food followed by 28 on nonnitrogenous food), excreted daily 1.42 grams nitrogen. The same dog after prolonged feeding upon low protein rations, however, showed in a three-days fast an average daily excretion of only 0.95 grams nitrogen. On the other hand, however, as already pointed out, the fasting protein katabolism may show a very marked increase with the progress of fasting in the absence of a sufficient store of body fat. It appears, then, that in fasting the protein katabolism is much more variable in amount than the total katabolism, and this fact must be remembered in any discussion of the protein requirement.

THE MINIMUM OF PROTEIN.[2]

It is evident that the comparatively small amount of protein katabolized in the fasting animal so long as its store of fat is reasonably abundant is at least all that is absolutely essential to the vital processes, since the latter go on for a considerable time in a substantially normal manner. The question at once arises whether this fasting katabolism represents the amount of digestible protein which must be supplied in the feed in order to maintain the protein tissues of the body.

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[1] Cited by Lusk.

[2] For a more exhaustive discussion of the subjects of this and succeeding paragraphs, including references to the literature, compare the references on page 8, in particular Magnus-Levy, pp. 198–423; Tigerstedt, pp. 391–480; Lusk, Chapters IV and V.

INFLUENCE OF NONNITROGENOUS MATERIALS.

In the first place, it is to be remarked that, as just shown, the protein katabolism during fasting is by no means a fixed and definite quantity, but may vary even in the same individual within quite wide limits both absolutely and as regards the proportion of the total energy requirement which is supplied by it. From the results cited on pages 12–13, it is evident that a most important factor influencing the fasting katabolism is the stock of fat in the body and that when the latter is reduced protein is katabolized for the sake of its energy. In other words, a lack of readily available nonnitrogenous material in the body tends to increase the protein katabolism above its minimum value. Evidently, then, in seeking to determine the minimum amount of protein required for maintenance, the food given should contain a liberal supply of nonnitrogenous nutrients to supply the necessary energy for the animal, since otherwise there is danger that the protein will be katabolized for this purpose, resulting in an apparent increase of the maintenance requirement.

RELATION TO FASTING KATABOLISM.

In the early experiments upon this subject, especially those of Voit, the full significance of this fact had not been recognized. His experiments, in which increasing amounts of protein alone were fed (compare p. 79), showed that protein equal to two and a half to three times the fasting katabolism was necessary to reach nitrogen equilibrium, and this result was generalized and passed current for a considerable time.

Munk[1] seems to have been the first to challenge this view and to claim not only that an amount of protein equal to that katabolized during fasting is adequate, but that with an abundant supply of nonnitrogenous material, especially carbohydrates, in the feed a notably smaller amount of protein is sufficient to maintain the nitrogen balance. Munk's experiments either include no comparison with the fasting katabolism of the same animal or a comparison not in all respects satisfactory, but they show clearly that nitrogen equilibrium was maintained on a supply of protein less than that usually found to be katabolized in similar fasting animals.

On the other hand, extensive experiments by Voit and Korkunoff[2] on dogs led these experimenters to an opposite conclusion. Starting with a ration deficient in protein but containing a very liberal supply of nonnitrogenous nutrients, the protein of the feed was gradually increased until an amount was reached sufficient to produce equilibrium between the income and outgo of nitrogen. Two series of experiments were performed, in one of which the nonnitrogenous nutrients consisted chiefly of fat, and another in which they consisted of carbohydrates. Considering only those experiments in which the feed consumed was more than sufficient in amount to supply the estimated demand of the body for energy, it was found that when the nonnitrogenous nutrients consisted of fat the nitrogen (protein) of the feed had to be increased to approximately 130 per cent of the amount katabolized in fasting before nitrogen equilibrium was reached—that is, before the stock of body protein was maintained. When, however, the energy demands of the body were supplied by carbohydrates instead of fats, a supply of nitrogen (protein) in the feed equal to or even somewhat less than the amount katabolized in fasting sufficed to insure nitrogen equilibrium.[1] Cremer and Henderson,[2] in experiments on a dog with a ration estimated to supply the necessary energy for maintenance, were unable to maintain nitrogen equilibrium on even as small an amount as did Voit and Korkunoff.

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[1] Virchow's Archiv für Pathologische Anatomie und Physiologie und für Klinische Medizin, vol. 101, p. 91; vol. 133, Supp.; vol. 132, p. 91. Archiv für (Anatomie und) Physiologie, 1896, p. 183.

[2] Zeitschrift für Biologie, vol. 32, p. 58.

In the case of man, on the other hand, numerous experiments seem to have demonstrated that an amount of feed protein notably less than the ordinary fasting katabolism is sufficient to maintain nitrogen equilibrium, although even in this case the comparison in nearly every case is with the average fasting katabolism and not with that of the individual under experiment. This average for man, however, has been well established by numerous experiments and seems not to vary widely for individuals, while in Benedict's experiments[3] upon nutrition after fasting a material diminution of the protein katabolism of the subject was observed on the second and third days. In every case the body lost protein, but in experiments 70 and 74 there was a storing up of energy.

Protein katabolism during and after fasting.[4]

	Experiments 69 and 70.	Experiments 71 and 72.	Experiments 73 and 74.	Experiments 75 and 76.
Fasting:	*Grams.*	*Grams.*	*Grams.*	*Grams.*
First day	60.5	35.0	61.7	73.4
Second day	85.6	66.2	71.8	74.7
Third day	90.2	78.6	69.2	78.1
Fourth day	77.8	64.4	62.3	69.8
Fifth day			59.9	65.2
Sixth day				64.4
Seventh day				60.8
Food after fasting:				
First day	78.24	63.96	64.44	61.02
Second day	59.04		49.50	42.90
Third day	60.90		40.68	46.92

Another factor which must be taken into consideration in fixing the minimum of protein is what may be called the time element. Rubner calls attention to the fact that if the protein of the ration is consumed at a single meal there may be for a time a surplus of protein or its digestive products in the system, while at a subsequent period of the day there may be a deficiency which will be made good by a draft upon the proteins of the tissues.

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[1] Voit and Korkunoff put a different interpretation upon their results, basing it upon the fact that a certain portion of the urinary nitrogen is derived from the nitrogenous extractives of the flesh metabolized in the body. Compare the account of their experiments in the writer's Principles of Animal Nutrition, pp. 135–139.

[2] Zeitschrift für Biologie, vol. 42, p. 612.

[3] Loc. cit., pp. 456 and 529.

[4] The odd-numbered experiments were the fasting experiments. The even-numbered are those in which food was given and which immediately followed the corresponding fasting experiments.

For the purpose of this discussion, it is unnecessary to pursue further the somewhat complicated question of the absolute protein minimum and its relations to the fasting protein katabolism, especially in view of the fact that, as has been shown, the latter is itself more or less variable. It appears well established that on a diet containing an abundance of carbohydrates a supply of protein equivalent to the fasting protein katabolism is sufficient to meet the needs of the organism, while it is possible that a less amount will suffice. Fats appear to be distinctly less efficient than carbohydrates in keeping the protein katabolism at the minimum. Precisely why this is the case has not been fully made out, although Landergren[1] has advanced the explanation that a minimum of carbohydrates is essential to the chemical processes of metabolism and that when a sufficient amount is not supplied in the feed, protein is katabolized for the sake of producing carbohydrates, with the result that on a low protein diet nitrogen katabolism is increased. In any case, it is clear that the protein requirement upon a mixed ration sufficient in quantity is comparatively small.

EFFECT OF SURPLUS OF PROTEIN.

INCREASES PROTEIN KATABOLISM.

But while a relatively small quantity of digestible protein is sufficient, in the presence of an abundant supply of fuel material, to maintain the body in nitrogen equilibrium, an increase of the feed protein above this minimum does not result in any large or long-continued gain of protein tissue by the mature animal, but causes a corresponding increase in the protein katabolism, as is shown by the prompt increase in the amount of nitrogen excreted in the urine.

This fact was demonstrated more than 50 years ago by C. Voit, in collaboration at first with Bischoff[2] and later alone and with Pettenkofer,[3] in experiments on carnivorous animals, and almost innumerable subsequent investigations have shown that it is true not only of these animals, but of man and of herbivorous animals as well. The protein katabolism is determined chiefly by the supply of digestible protein in the feed, and the body comes quite promptly into equilibrium with any amount above the maintenance requirement which can be consumed, the nitrogen of the excreta substantially equaling that of the feed. This is well illustrated by the following selection from Bischoff and Voit's results upon a dog,[4] arranged in the order of the amount of protein eaten.

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[1] Jahresbericht über die Forschritte der Tier-Chemie, vol. 32, p. 685.

[2] Gesetze der Ernährung des Fleischfressers, 1860.

[3] Published chiefly in the Annalen der Chemie und Pharmacie and the Zeitschrift für Biologie. See also Voit: "Physiologie des Stoffwechsels," in Hermann's Handbuch der Physiologie.

[4] Voit's compilation, Zeitschrift für Biologie, vol. 3, p. 5.

Daily protein katabolism of dog—Bischoff and Voit.

Dates.	Meat eaten.	Nitrogen of feed.[1]	Nitrogen excreted in urine.[2]
	Grams.	*Grams.*	*Grams.*
Nov. 26 to 27, 1858	176	6.0	12.6
Nov. 24 to 25	300	10.2	14.9
May 1 to 4, 1864	480	16.3	16.3
Apr. 20 to June 1, 1863	500	17.0	18.7
Nov. 22 to 23, 1855	600	20.4	22.9
Feb. 13 to 17, 1865	800	27.2	26.1
Nov. 20 to 21, 1858	900	30.6	31.7
Apr. 14 to 20, 1863	1,000	34.0	35.9
Nov. 18 to 19, 1858	1,200	40.8	41.1
Apr. 1 to 14, 1863	1,500	51.0	49.5
Mar. 25 to Apr. 1, 1859	1,800	61.2	59.7
Apr. 5, 1858	1,900	64.6	64.9
June 21 to 29, 1863	2,000	68.0	67.2
Jan. 22 to 25, 1858	2,200	74.8	71.9
Dec. 5 to 7, 1858	2,500	85.0	80.7
Jan. 25, 1858	2,660	90.4	84.5

Moreover, what has been shown to be true of an exclusively protein diet is substantially true also of one containing liberal amounts of fats or carbohydrates. Thus in the following selection from Bischoff and Voit's experiments[1] bearing upon this point it is clear that, notwithstanding the presence of considerable amounts of fat in the feed, the protein katabolism, as measured by the urinary nitrogen, increased substantially in the same ratio as the protein supply.

Daily protein katabolism of dog—Bischoff and Voit.

Dates (inclusive).	Feed.		Nitrogen of feed.[2]	Urinary nitrogen.[3]
	Fat.	Lean meat.		
	Grams.	*Grams.*	*Grams.*	*Grams.*
Nov. 22 to Dec. 1, 1857	250	150	5.1	7.3
Dec. 2, 1857	250	250	8.5	8.9
Dec. 5, 1857, to Jan. 5, 1858	250	500	17.0	14.4
Jan. 9 to 11, 1858	250	1,000	34.0	28.3
Jan. 15 to 18, 1858	250	1,500	51.0	45.9
Apr. 1 to 7, 1859	250	1,800	61.2	56.4
Jan. 13 to 14, 1859	250	2,000	68.0	63.4

Carnivorous animals have been extensively used in the investigation of such questions as the foregoing, and others which are to be discussed later, largely because with them it is possible to employ a diet consisting of but one or two simple nutrients, but the main facts which have been brought out by such investigations have been shown to be true also of herbivorous animals. In the latter, as in the carnivora, the protein katabolism is determined chiefly by the supply of protein in the feed.

As early as 1852, eight years before the publication of Bischoff and Voit's inevstigations, Lawes and Gilbert,[4] in discussing the results of theri fattening experiments upon sheep and pigs, called attention to the very wide variations in the amount of protein consumed, both per unit of weight and especially per unit of gain, and concluded that the apparent excess of protein in some cases must have served substantially for respiratory purposes.

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[1] Gesetze der Ernährung des Fleischfressers, 1860, pp. 97–115.

[2] Average of nitrogen of lean meat, 3.4 per cent.

[3] Computed from urea.

[4] Report British Association for the Advancement of Science, 1852, Rothamsted Memoirs, Vol. II.

Of the numerous later and more specific investigations on herbivora in which the nitrogen excretion has been determined, the following[1] may serve as an example. Two sheep were fed in periods 1 and 7 a basal ration of hay and barley meal. To this ration were added in the intermediate periods varying amounts of nearly pure protein in the form of conglutin (of lupins) or of flesh meal. A comparison of the nitrogen digested from the ration with the urinary nitrogen shows that the latter increased and diminished substantially parallel with the former.

Protein katabolism of sheep per day and head—Henneberg and Pfeiffer.

	Sheep I.		Sheep II.	
	Nitrogen digested.	Nitrogen in urine.	Nitrogen digested.	Nitrogen in urine.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Period 1	8.18	7.48	7.81	6.98
Period 2	17.86	16.82	17.72	16.37
Period 3	27.22	25.75	27.33	23.94
Period 4	36.99	32.71	37.07	32.09
Period 5	28.76	25.63	26.91	24.54
Period 6	17.62	16.64	16.94	15.99
Period 7	8.34	8.06	8.00	7.62

UTILIZATION OF PROTEIN LIMITED.

That the mere giving of protein food can not cause a large storing up of protein is indeed sufficiently obvious from daily experience. The muscles of the weakling can not be converted into those of the athlete by feeding him upon a meat diet, nor the small man increased in size by a very abundant protein supply. The protein tissues of the mature animal have reached their natural limit of size and consequently the capacity of the body to store up protein is limited. In such an animal, beyond the minimum required to make good the necessary katabolism in the cells protein can be utilized only to a small extent in the body as protein, and it is therefore rapidly katabolized, its nitrogen appearing in the urine as urea and other familiar end products. Nor is the situation essentially different in the growing or the milk-producing animal. While these animals are able to utilize considerable amounts of feed protein, yet the limit of this utilization is set by the normal rate of growth of the protein tissues or the capacity of the mammary glands to manufacture the casein and other proteins of the milk. Any surplus of protein over the amount which can be used for this purpose is katabolized precisely as is a surplus over the very small demand of the mature animal.

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[1] Henneberg and Pfeiffer. Journal für Landwirtschaft, vol. 38, p. 215.

As a single striking example there may be cited an experiment by Jordan,[1] in which the protein supply of cows, beginning with a liberal ration, was gradually diminished to about one-half and then gradually increased again to the original amount. The following table shows the average nitrogen balance of cow No. 12 of the second series of experiments, the daily results being grouped into periods as indicated.

Average daily nitrogen balance of cows—Jordan.

Date.	Number of days.	Nitrogen digested.	Nitrogen of milk.	Nitrogen of urine.	Gain by body.
		Grams.	*Grams.*	*Grams.*	*Grams.*
Jan. 30 to Feb. 6	7	186.6	81.7	87.0	+17.9
Feb. 6 to 16	10	185.2	81.4	87.5	+16.3
Feb. 16 to 26	10	161.6	77.5	81.9	+ 2.2
Feb. 26 to Mar. 8	10	130.8	74.0	56.5	+ .3
Mar. 8 to 18	10	117.2	66.6	43.7	+ 6.9
Mar. 18 to 28	10	143.6	69.6	61.8	+12.2
Mar. 28 to Apr. 7	10	171.4	71.6	89.2	+10.6
Apr. 7 to 14	7	185.7	71.9	104.4	+ 9.4

The amount of milk protein, like the total milk solids, diminished in quite a normal way with the advance in lactation, while the percentage of protein in the solids remained about the same. On the low protein rations of the middle periods there seems to have been some falling off in the amount of milk protein produced (and of the total milk solids as well) in comparison with what might have been expected on an unchanged ration, but the difference is small, except in one or two periods where the protein supply reached the lowest limit. Aside from this the principal effect of the variations in the amount of digestible protein supplied was to increase or diminish the amount of urinary nitrogen, which, as the table clearly shows, rose and fell with the supply of nitrogen in the feed.

PROTEIN AS A SOURCE OF ENERGY.

This increased katabolism of protein, however, is not to be regarded as a total loss of so much food material. The manner in which surplus protein is disposed of is rendered clear by a consideration of the chemistry of protein katabolism. Proteins are resorbed from the digestive tract in the form of comparatively simple cleavage products, chiefly amino-acids, and the body uses these nitrogenous cleavage products as building stones out of which to reconstruct body proteins broken down in the vital processes. As has just been shown, however, this necessary demand is relatively small, while the mature animal has lost the capacity which it had during growth of building up large amounts of new protein tissue. When the blood is, so to speak, flooded with these amino-acids in high protein feeding, some increase in the formation of body protein appears to result, as will be shown immediately, but this consumes a relatively small proportion of the nitrogenous matter and lasts for only a limited time. It is obviously an advantage to the organism, therefore, to be able to dispose of the surplus nitrogen. This it accomplishes by splitting off the NH_2 group and excreting it in the form of urea, etc., leaving a nonnitrogenous residue which contains the larger portion of the chemical energy of the protein which it represents and is in condition to be oxidized as fuel material. (Compare pp. 30–32.)

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[1] New York Agricultural Experiment Station, Bulletins 132 and 197.

The increased nitrogen excretion on a high protein diet is simply the method by which the organism gets rid of useless nitrogen, while retaining the larger share of the energy of the protein for fuel purposes. In other words the organism when confronted with a protein supply in excess of its needs is able by what seems to be a comparatively simple process to transform it into nonnitrogenous fuel material with but slight loss, getting rid of the useless nitrogen as urea through the urine. The increased nitrogen excretion consequent on high protein feeding does not mean the total destruction of the corresponding amount of protein, but simply its transformation into compounds which can serve as sources of energy.

STORAGE OF PROTEIN.

In the mature animal a surplus of feed protein is largely katabolized, so that a continued increase of the protein tissue of the animal can not be brought about, as can that of the adipose tissue, simply by a surplus in the feed. The protein content of such an animal, however, is not to be regarded as absolutely fixed, so that the protein supply has no effect upon it. On the contrary, a considerable range of variation is possible.

When the protein supply is increased, nitrogen equilibrium is not established at once, but for a time more or less storage of nitrogenous material takes place. For instance, when a dog in Voit's experiments[1] was changed from a ration of 500 grams of meat daily for 42 days to one of 1,500 grams, the urinary nitrogen showed the following behavior on the last three days of old feeding and on the first seven of the new:

Storage of protein by dog—Voit.

	Date.	Meat fed.	Nitrogen of feed.	Nitrogen of urine.[2]	Gain of nitrogen.
	1863.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Experiment No. 40	May 29	500	17.0	18.9	−1.9
	May 30	500	17.0	18.2	−1.
	May 31	500	17.0	17.7	− .7
Experiment No. 41	June 1	1,500	51.0	41.1	+9.9
	June 2	1,500	51.0	44.1	+6.9
	June 3	1,500	51.0	46.9	+4.1
	June 4	1,500	51.0	48.0	+3.0
	June 5	1,500	51.0	48.6	+2.4
	June 6	1,500	51.0	48.9	+2.1
	June 7	1,500	51.0	50.6	+ .4

Upon the lighter ration the animal was losing a small amount of protein daily. On the heavier ration there was a diminishing gain for six days, approximate equilibrium being reached on the seventh day. The total gain in the seven days was 28.8 grams nitrogen, equivalent to 847 grams of fresh flesh, or about 12 per cent of the surplus fed, equivalent to from 3.5 to 4 per cent of the amount probably present in the body of the 35-kilogram dog.

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[1] Zeitschrift für Biologie, vol. 3, p. 80.

[2] Computed from Voit's figures for urea.

In order to retain this protein which was stored up in the body, however, it was necessary to continue the heavier ration of 1,500 grams of meat. When, in previous periods of the same series, a ration of 1,500 grams of meat was followed by one of 1,000 grams and this by one of 500 grams, the protein previously stored up was rapidly katabolized again, as the following table shows:

Loss of protein by dog—Voit.

	Date.	Meat fed.	Nitrogen of feed.	Nitrogen of urine.[1]	Gain of nitrogen.
	1863.	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Experiment No. 38 (last 3 days)	Apr. 11	1,500	51.0	48.4	+2.6
	Apr. 12	1,500	51.0	50.9	+ .1
	Apr. 13	1,500	51.0	52.8	−1.8
Experiment No. 39	Apr. 14	1,000	34.0	38.6	−4.6
	Apr. 15	1,000	34.0	36.4	−2.4
	Apr. 16	1,000	34.0	36.4	−2.4
	Apr. 17	1,000	34.0	36.1	−2.1
	Apr. 18	1,000	34.0	34.3	− .3
	Apr. 19	1,000	34.0	35.2	−1.2
Experiment No. 40	Apr. 20	500	17.0	23.7	−6.7
	Apr. 21	500	17.0	20.4	−3.4
	Apr. 22	500	17.0	20.9	−3.9
	Apr. 23	500	17.0	18.8	−1.8
	Apr. 24	500	17.0	17.4	− .4
	Apr. 25	500	17.0	18.8	−1.8

The total loss of nitrogen from the body for the 12 days included in the table is 31 grams, or an amount about equal to that stored up in passing from the 500-gram to the 1,500-gram ration.

This comparatively small store of rapidly katabolizable protein in the body after liberal protein feeding Voit designated as circulatory protein, in distinction from the large mass of stable protein which he called organ protein. A variety of other names, corresponding to more or less definite theories as to the nature of the distinction between the two types of protein, have been proposed by later investigators, such as stable and labile, organized and unorganized, tissue and reserve, living and dead, protein. Still others, notably Gruber,[2] explain the temporary storage of nitrogenous matter in the body as due to a lag in the katabolism of protein, so that the splitting off of its nitrogen is not complete within the ordinary 24-hour period. The facts, however, that the nitrogen excretion follows in general the supply in the feed but that a temporary and limited storage of nitrogenous material in the body may result from liberal protein feeding, are undisputed.

FLUCTUATIONS IN BODY PROTEIN.

It is a familiar fact that a fasting animal may live and continue to perform the essential bodily functions for some time, while losing daily a not inconsiderable amount of protein. To cite a single striking example, Rubner observed in a fasting rabbit up to the time of death, on the nineteenth day, a loss of 45.2 per cent of the computed nitrogen of the body.[3] While this is an extreme case, nevertheless it is evident that there must be a relatively large loss of body protein in those more moderate cases in which the deprivation of protein is not continued so long as to cause death. Furthermore, the losses occurring in these latter cases may be made good by subsequent feeding and the animal restored to its original state. Striking examples of the same fact are familiar in the human subject in the emaciation due to long illness and the restoration of the body during convalescence. Pugliese[1] has shown that a similar storage of protein takes place rather rapidly in the liver when a previously fasted animal receives feed again. In brief, it is evident that the body of the mature animal may fluctuate within somewhat wide limits as regards its protein content without necessarily causing any serious or permanent derangement of its functions.

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[1] Computed from urea.

[2] Zeitschrift für Biologie. vol 42, p. 407.

[3] E. Voit. Zeitschrift für Biologie, Vol. 41, p. 139.

We can hardly suppose such a fluctuation to consist to any large extent of an actual destruction and rebuilding of the cells of muscular or other tissue, but must regard it as effected chiefly by changes in the amount of cell contents—an alternate atrophy and hypertrophy of the cells under the influence of the changing protein supply. This same conception may be invoked, however, to explain small as well as large fluctuations in the body protein. According to Rubner,[2] the cells of the body seek to maintain an optimum protein content, and in proportion as this becomes reduced they show a capacity for storing up protein, when a more abundant supply is offered in the feed, which is analogous to that observed during growth. On the other hand, when the supply of feed protein is insufficient, protein previously stored may be katabolized.

In other words, as regards its stock of nitrogenous material the organism may exist and function at a higher or lower level according to the amount of protein supplied in the feed, while for each level of protein stock a certain supply in the feed is necessary—that is, the protein required for maintenance varies. With carnivora on a largely protein diet, such as was used in Voit's experiments, the adjustment of the body to the protein supply seems to take place rather promptly. In the case of herbivora, however, the adjustment appears to be more gradual, possibly owing to the relatively large supply of nonnitrogenous ingredients in their feed, and apparently some gain of protein may continue for a considerable time, although when expressed as a percentage of either the total feed protein or of the body protein the gain is relatively small.

RELATION TO ENERGY SUPPLY.

The prime demand of the organism is for energy for the performance of its vital functions, and if necessary it will draw upon its own tissues for this purpose. No clear conception of the laws governing the protein metabolism can be reached without taking into consideration the energy relations.

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[1] Jahresbericht über die Fortschritte der Tier-Chemie, vol. 34, p. 520.

[2] Das Problem der Lebensdauer, etc.

Ordinarily, the nonnitrogenous nutrients of the feed constitute the principal source of this energy. The proteins, however, or at least the cleavage products of their digestion or transformation, readily undergo a process of deamidization by which their nitrogen is split off and excreted, leaving a nonnitrogenous residue which is available as a source of energy. It is evident, then, that the relative abundance or scarcity of the supply of nonnitrogenous nutrients to the cells of the body may profoundly modify the extent and character of the protein metabolism and consequently the magnitude of the protein requirement.

One instance of this effect is the so-called premortal rise of the protein katabolism of the fasting animal when the store of body fat is reduced below a certain level. (Compare pp. 12–13.) Here the relative deficiency of fuel material in the circulation causes an increased breaking down of the cell protein, presumably by hydrolytic cleavage and subsequent deamidization, its nitrogen being gotten rid of as urea, etc., and the nonnitrogenous residue serving as a source of energy in place of the lacking fat.

A precisely similar thing occurs when the nonnitrogenous nutrients in the feed are relatively deficient and is especially striking in their entire absence. It was pointed out on pages 75–78 that the protein katabolism during fasting is at least an approximate measure of the minimum protein requirement of the body, and that if this amount, or perhaps even less, be supplied in the feed, along with an abundance of nonnitrogenous material, the stock of protein in the body may be maintained. But if the experiment be made of supplying the minimum of protein without nonnitrogenous matter a very different result is obtained.

Thus in one such experiment by E. Voit and Korkunoff,[1] a fasting dog excreted about 4 grams of nitrogen per day, equivalent, of course, to a daily loss of about 24 grams of body protein, while in addition to this it must have been oxidizing considerable body fat. When, however, it was fed slightly more than 24 grams of protein[2] (4.1 grams nitrogen), with no other feed, its nitrogen excretion jumped to 5.56 grams per day, so that it was still losing daily 1.46 grams of nitrogen, equivalent to 8.76 grams of protein. Instead of the entire amount of protein in the feed being applied to make good the losses of protein tissue, over one-third of it was katabolized, its nitrogen appearing in the urine and its nonnitrogenous residue doubtless being used as fuel material. Protein rather more than equal to the 8.76 grams lost was then added to the ration, but again the protein katabolism increased and the body failed to maintain its stock of protein, and it was not until protein equal to about three times the fasting katabolism was fed that equilibrium was reached. The details of the experiments are shown in the following table, the results furnishing also a striking illustration of the interesting relations between protein supply and protein katabolism which had been demonstrated more than 30 years earlier by the classic experiments of Bischoff and Voit.

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[1] Zeitschrift für Biologie, vol. 32, p. 67.

[2] In the form of lean meat from which the extractives had been removed by treatment with water.

Effect of protein supply on protein katabolism of dog—E. Voit and Korkunoff.

	Nitrogen in—		
	Food.	Feces and urine.	Gain (+) or loss (−).
	Grams.	*Grams.*	*Grams.*
Nothing	0	3.996	−3.996
Extracted meat (grams):			
100	4.10	5.558	−1.458
140	5.74	6.496	− .755
165	6.77	7.217	− .447
185	7.59	7.804	− .214
200	8.20	8.726	− .526
230	10.24	10.579	− .339
360	11.99	12.052	− .062
410	15.58	14.314	+1.266
360	13.68	13.622	+ .058

It is clear that in the protein-fed animal, as in the fasting animal, the demands of the organism for energy take precedence over the need for repair material, and that in default of nonnitrogenous material the protein of feed or of tissue is seized upon and katabolized for this purpose even at the expense of a loss of body protein, the body seeming to find it easier to do this than to draw upon the stores of fat in the adipose tissues.

What is so strikingly true in the total absence of nonnitrogenous nutrients holds good also in less degree in case of their relative deficiency. If a portion of the nonnitrogenous nutrients are withdrawn from a mixed ration, the protein katabolism usually increases, while, on the other hand, if nonnitrogenous nutrients be added to such a ration the tendency is to diminish the protein katabolism. This well-known influence of the supply of nonnitrogenous nutrients upon the protein katabolism, even in an abundant ration, is well illustrated by some of Kellner's respiration experiments on cattle,[1] in which starch was added to a basal ration. The following table shows the average daily gain of nitrogen by the animal on the basal ration and the increased gain following the addition of starch.

Effect of nonnitrogenous nutrients on gain of protein by cattle—Kellner.

Animal.	Gain of nitrogen.		
	On basal ration.	With addition of starch.	Difference.
	Grams.	*Grams.*	*Grams.*
Ox D	12.75	13.71	+ 0.95
Ox F	5.64	26.37	+20.73
Ox G	−.03	17.09	+17.12
Ox H	7.23	12.95	+ 5.72
Ox J	5.49	15.06	+ 9.56

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[1] Die Landwirtschaftlichen Versuchs-Stationen, Band 53.

It has been shown that this effect is produced not only by the true fats and by the soluble hexose carbohydrates, such as starch and the sugars, but likewise, in the case of herbivorous animals, by those ill-known ingredients of feeding stuffs, especially of the crude fiber and the nitrogen-free extract, which disappear in the passage of the food through the alimentary canal and which are commonly spoken of as being digested. This statement covers also the organic acids, whether resulting from the fermentation of the carbohydrates or contained in the feed.[1]

We are not, however, to conceive of a sharp distinction in this respect between an insufficiency and a sufficiency of nonnitrogenous nutrients, but rather of a tendency on the part of the latter to diminish the protein katabolism, a tendency more or less marked according to their abundance in the ration. We are not to understand that no nitrogenous material is katabolized for fuel purposes as long as sufficient nonnitrogenous nutrients are present to supply the demands for energy, nor that even the largest quantities of the latter can prevent the katabolism of protein supplied in excess of the possible constructive use by the body. We may believe that the protein cleavage products, either derived from the feed or from tissue katabolism, are always present in the blood and that more or less deamidization is continually going on, resulting in a use of protein material as fuel. On the other hand, nonnitrogenous substances, derived from the feed or the body fat, are also present and take their share in supplying energy. We may probably conceive of the quantitative character of the katabolism as being determined, in a very broad sense, by the law of mass action. An increase of nonnitrogenous materials in the blood or lymph tends to diminish the deamidization and subsequent oxidation of the cleavage products of protein and through this, secondarily, to diminish the breaking down of body protein or to stimulate and prolong the limited storage of protein possible in the mature animal.

As regards the maintenance requirement, it is evident, then, that the sufficiency of a given amount of protein depends not only upon the plane of protein nutrition of the body, but also upon the amount of nonnitrogenous nutrients supplied with the protein. With an abundant supply of the former an amount of protein equal to the fasting katabolism, or perhaps even less, appears to be a sufficient minimum for maintenance. As the supply of nonnitrogenous materials is reduced a larger supply of feed protein seems to be required to reach equilibrium because more and more of it is diverted for use as fuel, so that in the total absence of nonnitrogenous nutrients a large excess of protein must be fed before equilibrium between income and outgo is reached. In interpreting experiments or formulating a maintenance ration, therefore, it is not sufficient to consider simply the amount of protein, but account must be taken of the supply of nonnitrogenous materials.

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[1] Compare Armsby, Principles of Animal Nutrition, pp. 117–127.

VALUE OF NONPROTEIN.

The crude protein of the feed of farm animals includes not only true protein but a great variety of other nitrogenous substances, grouped for convenience under the designation "Nonprotein." In considering the results of experiments upon the protein requirements of these animals, therefore, it is necessary to determine whether the true protein should be the basis of comparison or whether the nonprotein has some value for maintaining the protein tissues of the body.

The writer has recently[1] considered in some detail the experimental evidence on this point, and the discussion need not be repeated here. It appears to have been demonstrated by recent experimental results, especially by those of Kellner, Morgen, and the Laboratory for Agricultural Research in Copenhagen, that the nonprotein of ordinary feeding stuffs is available for the maintenance of ruminants, probably indirectly through a conversion to protein by means of bacteria in the digestive tract. On the other hand, investigations have not thus far shown that such nonprotein has any material value for production purposes. The writer therefore reached the conclusion that for the present, pending further investigation, it is desirable to consider ordinarily only the digestible true protein in the computation of rations for productive purposes, ignoring the nonprotein. This implies, however, that a discussion of the results of experiments upon the protein requirement shall also be based upon the amounts of true protein supplied and not upon the crude protein. This will have two effects.

First, it will make the protein requirement appear smaller than it really is. Suppose, for example, that a series of trials in which the ratio of digestible nonprotein to digestible protein is 1:10 shows that nitrogen equilibrium is reached with a ration supplying 500 grams protein and 50 grams nonprotein. Regarding the true protein only, the maintenance requirement is 500 grams, while the real requirement of the animal is 550 grams.

In the second place, however, this error will be largely compensated for when the actual computation of rations is also based on the true protein. Thus in the case just supposed, if a maintenance ration be computed from any feed or mixture in which the ratio of nonprotein to protein is the same as in the experiments from which the maintenance requirement was deduced, viz, 1:10, it is obvious that the same final result will be reached whether the maintenance requirement be considered to be 500 grams of true protein or 550 grams of crude protein. Only when the proportion of nonprotein to true protein varies widely from that existing in the rations used in determining the protein requirement will any significant error arise in computing rations.

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[1] Bureau of Animal Industry, Bulletin 139.

In the results considered on succeeding pages, both the crude protein and true protein of the rations are stated when these are given in the reports of the experiments.

MINIMUM OF PROTEIN FOR FARM ANIMALS.

In considering the protein supply of different species of farm animals, it is important to distinguish between two points of view. On the one hand, it may be sought to determine the least amount of protein upon which the protein tissues of the animal can be maintained. This might be called the physiological minimum. It shows the proportion of protein in a productive ration which is devoted solely to maintenance. On the other hand, the endeavor may be to formulate the most advantageous amount of protein to supply when an animal is actually to be maintained for a time and this amount may very possibly be greater than the physiological minimum. The first point of view, however, is plainly the fundamental one and should receive our first consideration. Having determined the lower limit of protein supply, it will then be possible to consider intelligently the advantages, if any, of a surplus.

CATTLE.

For obvious reasons it is impracticable to ascertain the fasting katabolism of ruminants; their maintenance requirement as regards protein must, therefore, be determined by a process of trial.

The earliest, and for a long time the only, determinations of the maintenance requirements of cattle were those of Henneberg and Stohmann in 1858, the results of which as regards energy were cited on page 39. In 6 experiments the minimum amount of digestible crude protein (total nitrogen × 6.25) supplied per day was 0.35 pound per 1,000 pounds live weight and this quantity seemed to be more than sufficient for maintenance. On the average of the 6 experiments, in 2 of which there was some loss of body protein, 0.53 pound of digestible crude protein was consumed per 1,000 pounds live weight. Wolff's standard for maintenance, long current, viz, 0.7 pound digestible crude protein, was based on Henneberg and Stohmann's experiments with an allowance for the fact that their experiments were made at a relatively high temperature. Wolff's standard, however, was intended as a guide for actual maintenance feeding rather than as an expression of the minimum protein requirement.

In the light of later experience, the methods of these earlier experiments must be considered imperfect and their results are now chiefly of historical interest. The first experiments by modern methods were those of G. Kühn and

Kellner at the Moeckern Experiment Station,[1] which include determinations of the gain or loss of fat as well as of protein and hence afford a secure basis for judgment as to the sufficiency of the energy supply. Including subsequent slight corrections by Kellner,[2] the principal results as regards protein are summarized in the following table:

Gain or loss of protein by cattle—G. Kühn and Kellner.

No. of animal.	Live weight.	Protein per day and 1,000 pounds live weight.			
		Digestible in feed.		Gain by animal.	
		Crude protein.[3]	True protein.[4]	Protein.	Fat.
	Pounds.	*Pound.*	*Pound.*	*Grams.*	*Grams.*
II	1,394	0.65	0.58	−17.2	+ 75.8
III	1,393	.53	.35	−24.5	+ 63.0
IV	1,386	.53	.34	−25.9	+ 20.4
V	1,327	.75	.60	+21.8	+106.6
VI	1,420	.71	.57	+11.8	+119.3
XX	1,481	.80	.65	− 3.2	+ 71.7
A	1,365	.71	.56	+27.2	+103.0
B	1,348	.35	.28	−65.3	− 78.0

If the very small loss of protein by ox XX may be regarded as falling within the limits of experimental error, the eight experiments may be averaged as follows:

Animal.	Digestible in feed.		Gain by animal.	
	Crude protein.	True protein.	Protein.	Fat.
	Pound.	*Pound.*	*Grams.*	*Grams.*
Animals V, VI, XX, and A	0.74	0.60	14.4	+100.2
Animal II	.65	.58	−17.2	+ 75.8
Animals III, IV, and B	.47	.32	−38.6	+ 5.4

It appears that approximately 0.6 pound of digestible true protein or 0.74 pound of crude protein per 1,000 pounds live weight was at least sufficient to rather more than maintain nitrogen equilibrium when the total energy supply in the ration was sufficient to cause a small gain of fat, while half this amount of true protein or 0.47 pound of crude protein was manifestly insufficient. A reduction to 0.35 pound digestible true protein or 0.53 pound digestible crude protein in the cases of ox III and ox IV, even with a sufficient supply of non-nitrogenous material to cause some gain of fat, resulted in a loss of protein from the body, while in the case of ox B, with a slightly lower supply of true protein and a materially lower one of crude protein and a ration materially below the maintenance requirement, the loss of protein was still greater. The considerable loss of protein by ox II is not readily explicable.

Experiments upon the same subject were also made by the writer[5] in 1892–1898, chiefly upon rations of timothy or mixed hay, with the addition in Experiment VII of starch, but also, in Experiment VIII, upon a ration consisting chiefly of grain together with a minimum of wheat straw. The results of these experiments are contained in the following table:

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[1] Die Landwirtschaftlichen Versuchs-Stationen, vol. 44, p. 257; vol. 47, p. 275.

[2] Die Ernährung der Landwirtschaftliche Nutztiere, 5th ed., p. 411.

[3] Corrected for estimated loss of nitrogen in drying of feces.

[4] As reported in the original account of these experiments.

[5] Pennsylvania Experiment Station, Bulletin 42, p. 165.

Nitrogen balance per 1,000 pounds live weight—Armsby.

Experiment.	Digestible in feed.		Nutritive ratio 1:	Gain or loss of nitrogen by body.
	Crude protein.	True protein.		
	Pound.	*Pound.*		*Grams.*
Experiment I:				
Steer 1	0.30	0.26	20.1	−2.7
Steer 2	.27	.23	20.4	− .4
Steer 3	.31	.27	18.6	−1.2
Experiment II:				
Steer 1	.45	.38	13.4	+1.9
Steer 2	.47	.40	13.6	+4.2
Steer 3	.49	.42	12.8	+5.2
Experiment VI:				
Steer 1	.62	.59	10.9	+4.7
Steer 2	.60	.55	10.9	+6.0
Steer 3	.67	.63	10.6	+2.8
Experiment VII:				
Steer 1	.49	.31	23.0	+5.7
Steer 2	.44	.26	25.3	+3.7
Steer 3	.51	.30	23.9	+4.4
Experiment VIII:				
Steer 1	.62	.52	10.4	+ .2
Steer 2	.57	.48	10.7	− .1
Steer 3	.66	.55	10.6	−2.0

In Experiments II, VI, VII, and VIII digestible crude protein ranging from 0.44 to 0.67 pound fully sufficed for maintenance, with a single exception. The range of true protein was somewhat wider, viz, 0.26 to 0.63 pound. The rations of Experiment VII were relatively richer in nonprotein than were those of the other experiments, and the adequacy of these very low protein rations suggests a utilization of the nonprotein, although the abundance of nonnitrogenous nutrients, as shown by the nutritive ratio, may also be a factor. The rations of Experiment I were obviously inadequate, even although the supply of nonnitrogenous matter was liberal.

Experiments upon a steer by Armsby and Fries[1] in which the respiratory products were determined gave results in general accord with those already cited. Computed per 1,000 pounds live weight, these results were as follows:

Nitrogen balance per 1,000 pounds live weight—Armsby and Fries.

	Digestible.		Gain or loss by body.	
	Crude protein.	True protein.	Nitrogen.	Fat.
	Pound.	*Pound.*	*Grams.*	*Grams.*
1902.				
Period A	0.45	0.36	− 9.1	−286.5
Period B	.52	.42	− 1.3	− 89.2
Period C	.53	.44	− .4	+ .6
Period D	.68	.55	+12.3	+ 16.8
1903.				
Period I	.66	.46	−16.4	−192.9
Period II	.51	.38	−15.0	−350.8
Period III	.70	.53	− 2.3	−169.7
Period IV	.97	.84	+ 9.2	+196.4
1904.				
Period I	.44	.34	− 9.5	−312.7
Period II	.74	.55	− .8	− 75.2
Period III	.60	.46	− .5	−155.4

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[1] Bureau of Animal Industry, Bulletins 51, 74, and 101.

In periods C and D of 1902 and period IV of 1903, the only ones in which maintenance was reached, the crude protein ranged from 0.53 to 0.97 and the true protein from 0.44 to 0.84. In a later series of experiments[1] on two immature steers, from 0.92 to 1.13 pounds of crude protein, or 0.69 to 0.77 pound true protein per 1,000 pounds live weight sufficed for maintenance in three periods in which there was some gain of fat. The experiments furnished no evidence that so large an amount was necessary, since the next lowest amount was 0.44 pound crude protein or 0.37 pound true protein in a ration producing a slight gain of fat but a small loss of protein.

The investigations of the Laboratory for Agricultural Research in Copenhagen upon the protein requirements for milk production include also two experiments on dry cows[2] with rations furnishing relatively small amounts of digestible nitrogenous matter, chiefly in the form of true protein. The periods in which an approximate nitrogen balance was secured gave the following data:

Nitrogen balance of dry cows per day and head—Copenhagen experiments.

Cow and period.	Live weight.	Crude protein (N. × 6.25) digested.		Gain of nitrogen per head by animal.
		Per head.	Per 1,000 pounds live weight.	
		Grams.	*Pound.*	*Grams.*
Cow 117:				
Period 2	488	87.5	0.18	−3
Period 4	485	100.0	.21	+2
Cow 134:				
Period 1	466	143.8	.31	−5
Period 4	443	112.5	.25	+3

The experiments on milking cows also afford approximate data as to the maintenance requirement. If the protein of the milk is subtracted from the total digestible protein of the feed, the remainder is obviously the maximum amount which was available for maintenance. In Bulletin 139 of this bureau, pages 38–39, there are given the results of those experiments in which the smallest amounts of protein were consumed. Selecting from among these those in which there was an approximate nitrogen equilibrium, we obtain the results tabulated below:

Daily gain or loss of protein by cows—Copenhagen experiments.

Cow and period.	Live weight.	Crude protein digested.	Protein of milk.	Maximum crude protein available for maintenance.	Gain of protein by animal.
Sixtieth report:	*Kilos.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Cow No. 10, period 6	446	600.0	387.5	212.5	−12.5
Cow No. 53, period 4	454	543.8	350.0	193.8	−12.5
Cow No. 53, period 6	451	568.8	306.3	262.5	+18.8
Cow No. 68, period 4	461	575.0	393.8	181.2	−31.3
Cow No. 68, period 14	441	506.3	312.5	193.8	−12.5
Cow No. 58, period 4	485	531.3	325.0	206.3	− 6.3
Cow No. 58, period 6	485	581.3	293.8	287.5	+37.5
Sixty-third report:					
Cow No. 68, period 6	453	575.0	368.7	206.3	−25.0

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[1] Bureau of Animal Industry, Bulletin 128.

[2] Sixty-third Report, pp. 28 and 30.

In the two periods in which there was a gain of protein by the animal the crude protein available for maintenance, computed per 1,000 pounds live weight, was:

	Pound.
Cow No. 53, period 6	0.58
Cow No. 58, period 6	.59

In the four periods in which the loss of protein by the animal did not exceed 12.5 grams (2 grams nitrogen) the corresponding amounts were:

	Pound.
Cow No. 10, period 6	0.48
Cow No. 53, period 4	.43
Cow No. 68, period 14	.44
Cow No. 58, period 4	.43

These results are quite of the same order as those obtained by Kellner and by Armsby, while those on the two dry cows are much lower, with the exception of a single result of Armsby's. (Experiment I, steer 2.)

In drawing conclusions from the results recorded in the foregoing pages, it is important to remember that what it is sought to determine is the minimum protein requirement. As has been shown on previous pages, an excess of feed protein above this minimum is, in the case of the mature animal, substantially all katabolized, producing no material gain of protein. The fact of an equality of income and outgo of nitrogen upon a given ration of protein, therefore, while it shows that the quantity consumed is sufficient for maintenance does not show that a smaller amount would not suffice. What we have to consider is the evidence of the experiments regarding the least amount sufficient for maintenance. It is evident that this minimum amount is relatively small, but it is also evident that the recorded results do not suffice to fix with certainty the absolute minimum.

The lowest recorded amounts per 1,000 pounds live weight upon which nitrogen equilibrium was reached were 0.21 pound and 0.25 pound of crude protein in the Copenhagen experiments on dry cows, while almost as small a quantity, viz, 0.27 pound crude protein or 0.23 pound true protein in Armsby's Experiment I, steer 2, fell very little short of reaching nitrogen equilibrium. Aside from these somewhat exceptional results, the lowest figures obtained per 1,000 pounds live weight were 0.43 pound crude protein and 0.38 pound true protein. The maximum is found in Armsby and Fries' experiment of 1903-4, viz, 0.96 pound crude protein and 0.84 pound true protein, but it seems altogether probable that the animal in this period was consuming a surplus of protein. If we omit these few extreme results in either direction, the average and range of the results of the other experiments are as follows:

Average and range of protein requirements of cattle.

	Number of experiments.	Protein requirement.		
		Average.	Maximum.	Minimum.
		Pound.	*Pound.*	*Pound.*
Crude protein	19	0.55	0.75	0.43
True protein	12	.52	.63	.38

It seems safe, therefore, to estimate 0.6 pound of crude protein or 0.5 pound true protein per 1,000 pounds live weight as representing in a general way the minimum protein requirement of mature cattle with a probable range of 0.1 or 0.2 pound either way under varying conditions.

For actual maintenance feeding it is probable that a somewhat more liberal supply of protein than is indicated by these figures would be advisable. Rations so poor in protein, if containing an adequate amount of nonnitrogenous matter, would probably suffer a loss through failure of the animal fully to digest the nonnitrogenous matter. A somewhat narrower nutritive ratio could readily be reached in practice in ordinary feeding without additional expense and from the standpoint of digestibility would very likely be justified.

SHEEP.

While a considerable number of experiments with sheep are on record in which approximate maintenance as a whole was observed, at least so far as could be judged from the live weight, few of them afford satisfactory data as to the minimum protein requirement. For the immediate purpose of this discussion, only experiments in which the nitrogen balance was actually determined are available, mere maintenance of weight being too uncertain a criterion.

A distinct difference between cattle and sheep, which affects the protein requirement, lies in the greater demand for protein incident to the growth of wool in the latter animals as compared with that of hair in the former. The results of determinations by Armsby and Fries[1] on the same two steers in two consecutive winters showed an average production of epidermal tissue, including the growth of hair and the loss in brushings, equivalent to 0.19 gram nitrogen per day and 1,000 pounds live weight, which is equal to 0.0025 pound protein, an amount too small to materially affect our estimates of the maintenance requirement. In the case of sheep, determinations of the growth of wool by several investigators afford the following data regarding the average amount of protein required for this purpose. The results have been computed per 1,000 pounds live weight for the sake of ready comparison:

Protein contained in daily growth of wool per 1,000 pounds live weight.

		Pound.
Henneberg, Kern, and Wattenberg[2]	Mature sheep	0.132
Henneberg, Kern, and Wattenberg[3]	Lambs	.143
Weiske[4]	Growing sheep	.100
Henneberg and Pfeiffer[5]	Mature sheep	.149
Pfeiffer and Kalb[6]	Mature sheep	.150
Average		.135

Although, as the foregoing figures show, the protein requirements of sheep for the growth of wool are considerably greater than those of cattle for the growth of hair, the absolute difference, after all, does not add very greatly to the total maintenance requirement.

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[1] Bureau of Animal Industry, Bulletin 128.

[2] Journal für Landwirtschaft, vol. 26, p. 549.

[3] Ibid., vol. 28, p. 289.

[4] Landwirtschaftliche Jahrbücher, vol. 9, p. 205.

[5] Journal für Landwirtschaft, vol. 38, p. 215.

[6] Landwirtschaftliche Jahrbücher, vol. 21, p. 175.

In Henneberg and Stohmann's Weende experiments[1] upon two sheep fed exclusively on meadow hay, there was digested on the average per 1,000 pounds live weight:

	Pounds.
Crude protein (total N × 6.25)	1.32[2]
Nitrogen-free extract	6.28
Crude fiber	3.93
Ether extract	.32

and the animal gained 0.17 pound of body protein, in addition to that stored in the wool, and a small amount of body fat.

In a series of 20 digestion and metabolism experiments by Schulze and Märcker,[3] decidedly smaller amounts of protein proved sufficient to maintain nitrogen equilibrium. In one case on a ration containing as little as 0.335 pound digestible crude protein per 1,000 pounds live weight, but having a very wide nutritive ratio (1:17.2) there was a slight gain of total protein, but one less than the amount required for the growth of wool. If we exclude this experiment and also 4 experiments in which it is evident that an excess of protein was fed, we have as the average of 6 experiments in which no loss of body protein was observed 0.653 pound digestible crude protein per 1,000 pounds live weight, while in two other experiments in which the minimum losses of 0.005 and 0.015 pound body protein were observed, the protein supply was, respectively, 0.655 and 0.690 pound. It is evident, then, that the protein supply of the sheep can be materially reduced below the amount fed in Henneberg and Stohmann's experiments without leading to a loss of body protein.

That such is the case seems to be clearly shown by the recent investigations of Katayama at the Moeckern Experiment Station,[4] in which increasing amounts of nearly pure protein ("aleuronat") were added to a basal ration very poor in protein, consisting of hay, oat straw, starch, and cane sugar. The protein in every case was substituted for a corresponding amount of starch, so that the total energy of the ration remained substantially unchanged. In the third period of the experiment both of the two sheep showed some loss of body protein, while in the fourth period, with more protein in the food, a gain was noted. In neither case was the growth of wool taken into consideration. By adding in the one case the loss of body protein to the digestible protein of the food and in the other period subtracting the gain, the author gets the following comparison:

Protein requirement of sheep per day and head—Katayama.

	Sheep I (weight, 34 kilograms).	Sheep II (weight, 38 kilograms).
	Grams.	*Grams.*
Period III:		
Nitrogen digested	1.978	2.412
Loss of body protein	.079	.216
	2.057	2.628
Period IV:		
Nitrogen digested	3.176	3.360
Gain of body nitrogen	1.107	.515
	2.069	2.845
Average for maintenance	2.063	2.737
Maintenance per 1,000 pounds live weight:		
Nitrogen	.061	.072
Protein	.379	.450

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[1] Neue Beiträge, etc.

[2] Estimated by Kellner to contain 1.04 pounds of true protein.

[3] Wolff: Die Ernährung der Landwirtschaftlichen Nutztiere, p. 300.

[4] Die Landwirtschaftlichen Versuch-Stationen, vol. 69, p. 321.

On the average of the two animals, 0.41 pound digestible crude protein per 1,000 pounds live weight was apparently sufficient to prevent a loss of nitrogen from the body. The crude protein in this case was practically all true protein, only minimum amounts of nonprotein being present in the ration. Since, however, the growth of wool must have gone on, with a corresponding storage of nitrogen, this apparent maintenance ration would really result in a loss of protein by the active tissues of the body.

If we add to Katayama's average 0.14 pound per 1,000 pounds live weight for the growth of wool, we get 0.55 pound as representing the minimum protein requirement for the maintenance of mature sheep, including the growth of wool. It is interesting to note that, according to these figures, the actual maintenance requirement for the body tissues is quite as low relatively as for cattle.

It is true that some earlier experiments seem to indicate a greater demand for protein than the foregoing figures show. Thus, in the experiments cited on page 80 to illustrate the influence of the protein supply upon its katabolism, a ration containing about 2.5 pounds digestible protein per 1,000 pounds live weight seemed to be about sufficient for maintenance, including the wool production, while a ration containing 2.27 pounds showed a loss of protein. Similarly, in earlier experiments by Henneberg, Fleischer, and Müller,[1] a ration containing 1.25 pounds digestible crude protein following one supplying 6.51 pounds resulted in a loss of protein by the animal. Notwithstanding these isolated results, however, it seems justifiable to accept the lower figure obtained by Katayama as representing approximately the minimum protein requirement of mature sheep.

SWINE.

The only data available as to the minimum protein requirement of swine are derived from the two experiments upon fasting animals by Meissl, Strohmer, and Lorenz (referred to on p. 51). The animals were Yorkshire swine, one 14 months old and weighing 140 kilograms, and the second, whose age is not given, weighing 120 kilograms. In the fasting state the nitrogen excretion of these animals was as follows:

	Live weight.	Nitrogen excretion.
Animal I:	*Kilos.*	*Grams.*
Average of first, second, and third days' fasting	140	9.80
Animal II:		
Average of third, fourth, and fifth days' fasting	120	6.77

The nitrogen excretion was equivalent, respectively, to 0.44 and 0.35 pound of protein per 1,000 pounds live weight, or about the amounts which appear to be required for cattle and sheep. No experiments are on record which demonstrate the sufficiency of this amount as a maintenance ration.

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[1] Jahresbericht der Agriculturchemie, vols. 16–17, II, p. 145.

THE HORSE.

In the experiments by Grandeau and Le Clerc described on pages 62–63 the nitrogen balance of the horses was determined during 6 of the periods. The following table shows the amounts of protein and of nonprotein nitrogen digested in each period, the urinary nitrogen, and the small losses in epithelial tissue (epidermis, hoofs, hair, etc.):

Nitrogen balance of horses—Grandeau and Le Clerc.

	Horse No. 1.		Horse No. 2.		Horse No. 3.	
	January, 1884.	April, 1884.	November, 1883.	May, 1884.	December, 1883.	March, 1884.
Digested:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Protein nitrogen	43.19	34.29	38.94	34.22	41.82	24.72
Nonprotein nitrogen	1.20	− 1.01	− 3.23	10.78	− 2.09	− 4.58
Total nitrogen	44.39	33.28	35.71	45.00	39.73	20.14
Nitrogen of epithelial tissue	1.46	1.46	1.46	1.46	1.46	1.46
Urinary nitrogen	35.17	38.75	30.70	41.92	37.62	32.70
Nitrogen gained	7.76	− 6.93	3.55	1.62	.65	−14.02

Omitting the results upon horse No. 3 in March, when the digestible protein was exceptionally low, the other five periods show an average daily gain of nitrogen of 1.33 grams, while the average crude protein digested (total N.×6.25) was 235 grams, equivalent to 0.59 pound per 1,000 pounds live weight.

THE OPTIMUM OF PROTEIN.

The data of the foregoing paragraphs seem to indicate a striking uniformity in the minimum protein requirement of the principal species of domestic animals when mature, 0.4 to 0.6 pound per 1,000 pounds live weight apparently sufficing to maintain nitrogen equilibrium under favorable conditions.

It should be clearly understood, however, that this figure represents a more or less accurately determined limit. It purports to be the amount below which the protein supply can not be reduced without eventual protein starvation. The animal body, however, may adjust itself to a wide range of protein supply above the minimum, using some of it to increase the stock of protein in the body and katabolizing the remainder as fuel material. An increase in the protein supply above the minimum results, after a relatively short time, in the maintenance of the body protein at a higher level. The practical question in actual maintenance is far less in regard to the least amount of protein which may be used than as to the most advantageous level of protein nutrition; that is, as to the optimum of protein.

This question has been warmly debated in connection with human nutrition.

Numerous recent investigations, notably those by Chittenden and his associates,[1] have shown that the protein of human dietaries can be reduced much below the amount previously regarded as necessary. In most cases there is no possibility of a direct comparison with the fasting katabolism of the same individual, but as previously stated (p. 77) a considerable number of instances are on record in which the nitrogen supply has been reduced to an amount materially lower than that usually found for the fasting protein katabolism of individuals of the same weight without leading to a loss of protein from the body. In all these experiments, the nonnitrogenous nutrients consisted, as is usually the case in human dietaries, to a considerable extent of carbohydrates. Moreover, while some of the earlier experiments were for short periods and on comparatively few individuals, Chittenden's investigations covered long periods and were made on 26 different individuals, including 5 professional men under observation for 8 months, 13 soldiers observed for 6 months, and 8 trained athletes under observation for 5 months. His results clearly demonstrate the possibility of maintaining the body protein and fully preserving the health and vigor upon a low protein diet. In other words, a relatively low level of protein nutrition for several months is not inconsistent with health and efficiency.

In some of the earlier experiments in which very low protein diets were fed to dogs, the health of the animals suffered seriously and there has been a tendency to ascribe these ill effects to the continued use of very small amounts of protein. Later investigations by Chittenden, however, in which dogs were kept on a low protein diet for the greater part of a year, seem to have demonstrated that the ill effects observed in the earlier experiments were due to unhygienic conditions and not to the low protein diet. It may be remarked that in experiments upon cattle, rations very low in protein have been fed for a considerable time without any perceptible deleterious effects. No similar determinations upon other species of farm animals appear to have been made.

On the whole, then, it can not be said that a considerable surplus of protein over the minimum requirement for maintenance—that is, the maintenance of protein nutrition on a high plane—has been proved to be of any material advantage in the maintenance either of men or domestic animals during periods covering several months. Whether a continued low protein diet through years or generations would show a different result is at present largely a matter of speculation. It is to be remarked, however, that the particular point under discussion is the protein requirement of the mature organism. That a deficiency of protein in the diet of a growing animal may have disastrous results is clear. If, however, the habitual food supply of a race of men or a group of animals is low in protein, the young are likely to share this deficiency with the mature, and it seems not impossible that this is an important factor in the alleged physical inferiority of certain races of men living on a low protein diet. This consideration warns us to exercise care in this respect in the management of the breeding herd.

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[1] Physiological Economy in Nutrition. Stokes Co., 1907.

In the actual maintenance feeding of farm animals, the matter of the digestibility of the ration must also be considered. It has been shown that a relative deficiency of protein in the ration tends to depress the apparent digestibility of both the protein and nonnitrogenous nutrients, especially in the case of ruminants. A maintenance ration for these animals containing the minimum amount of protein, together with the quantities of nonnitrogenous nutrients required to maintain the energy supply, would have a nutritive ratio, computed in the ordinary way, of approximately 1:12. On such a ration, there would, in all probability, be some loss of digestibility. An increase of its protein by 50 per cent would very probably effect a gain in digestibility which would more than offset the increased cost, if any. Indeed, unless feeds especially poor in protein are used, it may often be difficult, even if desirable, to reduce the protein content of a maintenance ration to the low level of absolute necessity.

RELATIVE VALUES OF PROTEINS.

In the discussions of the foregoing paragraphs, following the usual practice, the word protein has been used as if it designated a single chemical individual. In reality, of course, this is very far from being the case. The protein of the body or of the feed in this conventional sense includes a large number of distinct and in some respects, widely differing proteins. The studies of the chemical structure of the protein molecule made in recent years, beginning with the fundamental investigations of Emil Fischer, have shown marked differences in the proportions of the various "building stones" (amino-acids, etc.) contained in different proteins, while studies in immunity have led to the recognition of marked specific and individual biological differences in animal proteins, although these have not been definitely correlated with differences of chemical constitution. It is pertinent to inquire, therefore, whether we are justified in discussing the nutritive functions of feed protein as a group or whether we must consider each individual protein by itself. In other words, are there recognizable differences in nutritive value between individual proteins?

DIFFERENCES IN CONSTITUTION OF PROTEINS.

In discussions of this question, the chief emphasis has been laid upon the demonstrated differences in the proportions of the various cleavage products yielded by the different proteins when subjected to acid hydrolysis. The following table shows some of the more recent results obtained by Abderhalden and by Osborne:

Constituents of proteins—Abderhalden and Osborne.

Constituents.	Gliadin of wheat.[1]	Glutenin of wheat.[1]	Zein of maize.[1]	Phaseolin of white bean.[1]	Casein.[2]	Egg albumin.[2]	Serum albumin of horse blood.[3]	Serum globulin of horse blood.[2]	Ox muscle.[3]	Edestin from hemp.[4]
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Glycocol	....	0.89	....	0.55	0.00	0.00	0.0	3.5	2.06	3.80
Alanin	2.00	4.65	....	1.80	.90	2.10	2.7	2.2	3.72	3.60
Amino-valerianic acid	.21	.24	....	1.04	1.00	....	....	(5)	.81	(5)
Leucin	5.61	5.95	....	9.56	10.50	6.10	20.0	18.7	11.65	20.90
Prolin	7.06	[6] 4.23	....	2.77	3.10	2.25	[1] 1.0	[1] 2.8	5.82	[6] 1.70
Phenylalanin	2.35	1.97	....	3.25	3.20	4.40	3.1	3.8	3.15	2.40
Aspartic acid	.58	.91	....	5.24	1.20	1.50	3.1	2.5	4.51	4.50
Glutamic acid	37.33	23.42	16.87	14.54	11.00	9.10	7.7	8.5	15.49	[7] 6.30
Serin	.13	.74	....	.38	.23	....	.6	....	(?)	.33
Tyrosin	1.20	4.25	....	2.17	4.50	1.10	2.1	2.5	2.20	2.10
Cystin	.45	.02	....	....	.06	.20	2.3	.7	....	.25
Lysin	.00	1.92	.00	3.59	5.80	....	....	....	7.59	1.00
Histidin	.61	1.76	.81	1.97	2.59	....	....	....	1.76	1.10
Arginin	3.16	4.72	1.82	4.72	4.84	....	....	....	7.47	11.70
Ammonia	5.11	4.01	3.61	2.06	1.95	1.63	....	....	1.07	....
Tryptophan	(5)	(5)	.00	(5)	1.50	(5)	(5)	(5)	(5)	(5)
Total	65.81	59.66	23.11	53.64	52.37	28.38	42.6	45.2	67.30	....

[1] Osborne. The proteins of the wheat kernel, pp. 110, 113, and 118.

[2] Abderhalden. Lehrbuch der physiologischen Chemie.

[3] Osborne. The American Journal of Physiology, vol. 24, p. 437.

[4] Abderhalden. Loc. cit.

[5] Present.

[6] A prolin.

[7] A later determination by Osborne (American Journal of Physiology, vol. 15, p. 333), confirmed by Abderhalden, gave 18.74 per cent.

While many of the figures of the foregoing table can not lay claim to a high degree of quantitative accuracy, it is, nevertheless, clear that the proportions of the various atomic groupings in the protein molecule vary within wide limits, while in some cases the most careful search has failed to show the presence of certain constituents. Thus, glycocol and lysin were not found in gliadin, nor lysin and tryptophan in zein, while ox muscle yielded a considerable percentage of lysin, a moderate amount of glycocol, and showed the presence of tryptophan.

ABSENCE OF CERTAIN CONSTITUENTS.

There is now a general agreement that in the process of digestion the proteins of the feed undergo extensive cleavage and are to a large extent broken down either into individual amino-acids or into comparatively simple peptid-like compounds. These substances are resorbed by the intestinal epithelium and the diverse proteins of the body are formed from them by synthetic processes, either in the intestinal wall or beyond. Such being the case, it has seemed clear that, for example, the proteins of ox muscle containing 2.06 per cent of glycocol and 7.59 per cent lysin could not be produced from gliadin, which is lacking in both these groups, nor from zein, which lacks lysin and tryptophan.

The classic example of the effects of such a deficiency is, of course, gelatin, which contains neither tyrosin, cystin, nor tryptophan. Bischoff and Voit[1] long ago showed that gelatin in whatever amount fed is completely katabolized in the body, at least so far as its nitrogen is concerned, although it may somewhat diminish the waste of protein tissue. Subsequent investigations by Kirchmann[1] and by Krummacher[2] showed that when gelatin is fed alone an amount equivalent to the fasting nitrogen katabolism may reduce the loss of nitrogen from the body by something over 20 per cent, while, on the other hand, even very large quantities can effect a reduction of only about 35 per cent. Murlin[3] finds that in the mixed diet of men about two-thirds of the protein may be replaced by gelatin without disturbing existing nitrogen equilibrium. That the inferior value of gelatin is due to the absence of certain groupings in its molecule seems to have been shown by Kaufmann,[4] who found that gelatin with the addition of proper quantities of tyrosin, cystin, and tryptophan was able to maintain nitrogen equilibrium at least several days.

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[1] Hermann's Handbuch der Physiologie, vol. 6, pp. 122 and 395.

Investigations by Wilcock and Hopkins[5] upon zein, which, as already noted, lacks lysin and tryptophan, approach the subject from a slightly different angle. They found that a diet containing zein as its only protein material was unable to maintain growth in young mice. The addition of tryptophan approximately doubled the survival period and added markedly to the well-being of the animals, but was unable to maintain life indefinitely. On the zein diet the animals became torpid early in the experiment and almost comatose before death ensued, while with the addition of tryptophan no such symptoms were observed. The authors interpret this result as showing that tryptophan has some specific function in the body aside from the mere maintenance of nitrogen equilibrium. The results recently obtained by Osborne and Mendel,[6] however, show that great caution is necessary in the interpretation of such survival experiments, while they also indicate that growth is largely dependent on some other factor than the protein supply.

Experiments on rats by Henriques[7] gave a similar result as regards zein, with which it was found impossible to obtain nitrogen equilibrium in short experiments. On the other hand, however, an abundant supply of gliadin maintained nitrogen equilibrium for some days, notwithstanding the fact that it lacks both lysin and glycocol.

PROPORTIONS OF CONSTITUENTS.

Still further, even when all the constituents of the body protein are present in the feed protein, their proportions may be widely different. Thus, a mixture of equal parts of glutenin and gliadin would contain about 30 per cent of glutamic acid as compared with about half that amount in ox muscle, while the latter yields over 11.5 per cent of leucin as compared with less than 6 per cent from the former. In such a case it would seem that the tissues in which the synthesis takes place must make a selection from the material supplied by the digestive tract, reproportioning the various constituents, while the excess of certain ones would be attacked by the deamidizing enzyms of the body, their nitrogen being finally excreted as urea. Accordingly, it might be anticipated that the more nearly the feed protein resembled in its make-up the average of the body proteins the more economically it could be utilized for the building up or repair of protein tissues, and that thus there might be very considerable differences in nutritive value between different proteins.

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[1] Zeitschrift für Biologie, vol. 40, p. 54.

[2] Zeitschrift für Biologie, vol. 42, p. 242.

[3] American Journal of Physiology, vol. 19, p. 285; vol. 20, p. 234.

[4] Archiv für die Gesammte Physiologie des Menschen und der Thiere (Pflüger), vol. 109, p. 440.

[5] Journal of Physiology (London), vol. 35, p. 88.

[6] Carnegie Institute of Washington, Publication No. 156.

[7] Zeitschrift für Physiologische Chemie, vol. 60, p. 105.

EXPERIMENTAL METHODS.

Considerations like the foregoing have been advanced by numerous authors, but as yet little satisfactory experimental work upon the relative values of the proteins has been reported. Indeed the problem is far from being an easy one. Aside from technical difficulties, it is, of course, a simple matter to substitute one protein for another in the ration; the difficulty lies in finding a satisfactory measure of the effects. The most obvious thing, of course, is a determination of the balance of income and outgo of nitrogen, which, when extended over reasonably long periods, affords an approximate measure of the relative gain or loss of protein. As has been clearly shown on preceding pages, however, the nitrogen balance, especially in a mature animal, is a more or less fluctuating thing, being materially affected by various factors besides the momentary protein supply. Especially important are the influence of the previous protein supply upon the general level of protein nutrition, the influence of the store of body fat carried by the animal, and the supply of available energy in the feed. Only after these influences have been eliminated as completely as possible can differences in the nitrogen balance be ascribed to differences in the nature of the proteins consumed. On this account, experiments in which additions of protein are made to a ration already containing a considerable supply and in which gains of nitrogen in different periods are made the basis of comparison are quite unsatisfactory, as Magnus-Levy[1] has pointed out. A more satisfactory basis of comparison is the amounts of the different proteins required to maintain nitrogen equilibrium under conditions otherwise comparable. Furthermore, the protein supply must not be too liberal. Protein supplied in excess of the minimum requirement is utilized largely as fuel material. Under such circumstances, it is easily conceivable that proteins differing widely in constitution may furnish enough of each of the essential cleavage products to meet the relatively small demand for the maintenance of tissue and that thus differences really existing may be masked by the excess of protein supplied.

These considerations clearly indicate that the most promising method of investigation is to compare the minimum amounts of the different proteins required, along with an abundance of nonnitrogenous nutrients, to maintain nitrogen equilibrium on as low a plane of protein nutrition as practicable in the same animal in like bodily states and under identical conditions, so far as it is possible to insure these. Any consistent differences appearing in a considerable number of trials may then, it would seem, be safely ascribed to differences in the nature of the proteins.

Thus far but three investigations, according to the general method just outlined, have been published, all of them appearing within the year 1909. For the present purpose it seems superfluous to review the older investigations, made by less satisfactory methods and in many cases from a different point of view.

MICHAUD'S INVESTIGATIONS.

Michaud[2] experimented on three dogs by substantially the method just outlined. Reasoning that any loss in transforming feed protein into body protein would be smaller the less the difference in the constitution of the two, he used as his standard protein supply either dog flesh or the ground flesh and internal organs (heart, liver, spleen, and testicles) of dogs. This material may be assumed to have supplied the various amino acids, etc., in approximately the proportions required to maintain the protein tissues of the experimental animals with a minimum of loss. With this were compared gliadin and edestin as representatives of the vegetable proteins differing quite widely from those of the body and casein as an animal protein more or less similar to the tissue proteins.

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[1] Von Noorden's Handbuch der Pathologie des Stoffwechsels, vol. 1, p. 78.

[2] Zeitschrift für Physiologische Chemie, vol. 59, p. 405.

The series of experiments on the first dog affords a striking illustration of the difficulties in the way of successful investigation of this question. After fasting for 16 days and receiving only nonnitrogenous feed[1] (sugar and lard) for 28 days more, the daily nitrogen excretion (feces and urine) was reduced to 1.42 grams per day and appeared to have become approximately constant. Quantities of the various protein materials containing this amount of nitrogen were then added in successive periods to the basal nonnitrogenous ration and the effect upon the nitrogen balance determined, the periods covering from 6 to 9 days each. In three periods in which dog flesh was fed, the animal gained small amounts of nitrogen (0.08 to 0.17 gram per day); in other words, an amount of protein equal to the fasting katabolism sufficed to produce nitrogen equilibrium. Practically the same result was also attained in the period in which "Nutrose" (a preparation of casein) was fed. Three periods with gliadin, on the contrary, showed in every case a loss of nitrogen ranging from 0.33 to 0.52 gram per day; that is, the gliadin appeared decidedly less valuable than the dog flesh or casein for the maintenance of the body protein. Upon adding more gliadin to the ration it was found necessary to increase the daily amount to the equivalent of about 3.5 grams of nitrogen before nitrogen equilibrium was reached.

At the conclusion of this series, however, two 3-day periods on the nitrogen-free ration (preceding and following the period with the larger amount of gliadin) showed that the prolonged feeding on rations poor in protein had so lowered the plane of protein nutrition that the daily fasting katabolism was now equivalent to only 0.95 gram of nitrogen, or on the average of the last two days of each period to only 0.82 gram. In other words, the 1.42 grams of the earlier periods did not represent the absolute minimum on which life could be maintained. A second series of trials was therefore instituted in which dog tissue was compared with casein and edestin. In no case was nitrogen equilibrium quite reached, but the dog flesh still showed a decided advantage over the other forms of protein. The dog, however, had become very much reduced and died during the final period on dog flesh, the autopsy showing an exceedingly anemic condition. The attempt to base the comparisons of the different proteins upon the absolute minimum of the protein katabolism, in other words, involved such a reduction in the stock of body protein and consequently such an abnormal condition of the animal as to render the value of the results questionable. In succeeding experiments on two other dogs, therefore, the attempt to reach the absolute minimum of the protein katabolism was abandoned and the amounts of the several proteins added to the basal nonnitrogenous ration were either made equivalent to the fasting katabolism in the first period or reduced slightly below it according to the judgment of the experimenter. The results were in accord with those of the first series, the vegetable proteins, gliadin and edestin, proving notably inferior to the dog flesh or the casein.

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[1] No mention is made of any supply of ash ingredients other than those contained in the various forms of protein used, with the exception of a small amount of calcium carbonate (p. 423).

Upon two points, however, Michaud's results seem open to question. First, the pure proteins which he employed, as well as the sugar and lard, can have contained but minimal amounts of ash, while, as already stated, no mention is made of the addition of any ash ingredients except calcium carbonate. In those periods, then, the animal was apparently in a state of partial or entire mineral hunger. The dog flesh (or in two periods horse flesh), on the other hand, contained its normal amount of ash, and it is not impossible that this was an important factor in determining its higher value, although it must be admitted that this explanation does not apply to the casein periods. Second, dog tissue or horse flesh is by no means pure protein, but in addition to ash constituents contains a great variety of organic compounds, which may have been quite as important as the protein. In other words, the periods on tissue are not comparable with those on pure proteins.

ZISTERER'S EXPERIMENTS.

Zisterer[1] has reported two series of similar experiments, also on a dog. They differed from Michaud's, however, in that the periods were shorter and that each feeding period was interpolated between two periods on a nonnitrogenous basal ration from the average results of which the fasting protein katabolism of the animal for that particular bodily condition was computed. Zisterer experimented with casein, wheat gluten, and lean meat extracted with water (muscle protein). He added to his rations the chlorids of sodium, potassium, and calcium, but no other ash ingredients. The ash content of the feeds was small. The energy supply in the feed was in every instance ample to supply the needs of the animal as computed according to E. Voit.[2] Taking the first period, on casein, as an example, the preliminary period on nitrogen-free feed covered five days and the one following the feeding period four days. On the average of the last two days of these periods, the fasting protein katabolism was equivalent to 1.975 grams nitrogen daily. During the intermediate 4-day period, casein containing 2.018 grams nitrogen per day was fed and the average daily nitrogen excretion for the last two days was found to be 2.333 grams. Two series of trials of this sort, made in inverse order, yielded the following results:

Protein metabolism of a dog—Zisterer.

	Fasting nitrogen katabolism.	Feed nitrogen.	Total nitrogen excretion.	Gain of nitrogen by animal.
Series I:	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Casein	1.975	2.018	2.333	−0.315
Muscle protein	2.125	2.021	2.316	− .294
Wheat gluten	1.951	2.017	2.113	− .096
Series II:				
Wheat gluten	1.800	2.111	2.276	− .165
Muscle protein	1.806	2.110	1.903	+ .207
Casein	1.708	2.108	2.050	+ .058
Average:				
Casein	1.842	2.063	2.192	− .129
Muscle protein	1.966	2.066	2.109	+ .043
Wheat gluten	1.876	2.064	2.195	+ .131

If we represent the total nitrogen excretion upon the muscle protein by 100, that observed with the other proteins was as follows:

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[1] Zeitschrift für Biologie, vol. 53, p. 157.

[2] Ibid., vol. 41, p. 113.

Relative nitrogen excretion on different proteins.

	Series I.	Series II.	Average.
Casein	101	108	104
Muscle protein	100	100	100
Wheat gluten	91	120	104

Compared in this way, the differences disclosed between the different proteins are small in themselves, and, especially in the case of the wheat gluten, are discordant in the two series. Apparently the differences are less than those which may be plausibly ascribed to variations in the conditions of the several experiments. The latter may be to some degree eliminated by comparing the total nitrogen excretion with the fasting nitrogen katabolism of the corresponding periods. If the latter be represented by 100, the relative nitrogen excretion on the several proteins was as follows:

	Series I.	Series II.	Average.
Casein	118.1	120.0	119.1
Muscle protein	109.0	105.4	107.2
Wheat gluten	108.3	126.5	117.4

This second method of comparison seems to indicate a distinct, although small, inferiority of the casein as compared with the muscle protein. The same is true of the average result with wheat gluten, but not of the results of the individual series. Entirely similar results are obtained if the calculation is made only upon the protein nitrogen of the feed and excreta instead of the total nitrogen. Zisterer's results are, of course, open to the same criticism made on Michaud's, viz, that the so-called muscle protein was not comparable with the pure proteins used in the other periods.

RESULTS ARE QUALITATIVE.

Both Michaud's and Zisterer's results are in a sense qualitative. They show that certain foreign proteins when substituted for tissue caused a relatively greater nitrogen excretion and were therefore less efficient in maintaining the nitrogen balance of the body. For gliadin and edestin, Michaud observed a notably greater difference than did Zisterer for wheat gluten. For casein their results are quite similar. In no case was the amount of foreign protein required to reach nitrogen equilibrium determined, with the exception of one short period upon gliadin in Michaud's experiments. In both cases, the differences appear relatively small. On the basis of average figures for the proportions of four of the principal amino-acids in the different proteins, Zisterer computes much greater possible differences. Representing the amount of muscle protein required to furnish a given amount of each one of the four amino-acids by 100, Zisterer calculates that the following amounts of casein and of wheat gluten would be required for the same purpose:

	Muscle protein.	Casein.	Wheat gluten.
To furnish equal amounts of:			
Alanin	100	444	267
Leucin	100	74	154
Glutamic acid	100	124	49
Tyrosin	100	47	102

As was noted above, the ash supply was but partially considered in Zisterer's experiments, no mention being made of the addition of ash ingredients with the exception of sodium, potassium, and calcium. It seems not impossible that the phosphorus compounds of the muscle protein may have had something to do with its apparently greater availability.

THOMAS'S EXPERIMENTS.

Thomas[1] has attempted to determine the relative values of the mixed proteins of different foods by a method differing somewhat from that employed in the two foregoing investigations. As has been shown in previous pages, on an abundant nonnitrogenous ration, especially of carbohydrates, the protein katabolism of the body may be reduced to a very low limit which represents more or less exactly the minimum amount of protein necessarily broken down in the vital activities. If a small amount of protein be added to such a nonnitrogenous ration, it will tend to be used to replace body protein, since the surplus of nonnitrogenous material tends to prevent its being katabolized to furnish energy. The extent, then, to which any given protein under these conditions diminishes the loss of protein from the body may be taken as the measure of its maintenance value. The principle of the method may be illustrated by the following supposititious case.

	On protein-free food.	On protein food.
Protein digested	0	4
Protein katabolized	6	7
Loss of protein from body	6	3

In this case, four parts of food protein obviously replace three parts of body protein and the percentage availability of the former is therefore 75. The principle of the method is similar to that of the determination of the percentage availability of energy (p. 27).

It is to be remarked concerning this method, first, that it assumes that the percentage availability of the food protein is the same for all amounts below the maintenance requirement; in other words, that it is a linear function. This is an unproved assumption, and in view of the readiness with which protein or its cleavage products in the body seem to be deamidized and utilized as fuel, the assumption seems of questionable validity.

Second, in applying the method it is necessary to know accurately the minimum amount of protein katabolized on a nitrogen-free diet, since any error in the determination of its quantity seriously affects the final result. The protein katabolism, however, under these conditions, is not a constant quantity, as has already been pointed out, but varies more or less, especially with the state of protein nutrition of the cells. Accordingly, it must be determined as accurately as possible for the subject at the time of the experiment, preferably immediately before and immediately after.

Third, the amount of protein fed must be less than that katabolized on the nitrogen-free diet. If an excess of protein be consumed, the additional amount will tend to be katabolized and used as fuel, thus rendering the comparison between the two periods illusory, since it is obvious that any such oxidation of protein would tend to make its availability appear too low. Thomas's experiments were made upon himself and included four series, two in May to

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[1] Archiv für (Anatomie und) Physiologie, 1909, p. 219.

July and two in September to November of the same year. He determined his protein katabolism upon a nonnitrogenous diet (chiefly carbohydrates) in three or four day periods in each series and also interpolated single nitrogen-free days during each series. The results of these periods were more or less variable, but the final values employed by him, although representing to some degree an arbitrary selection of days, seem, on the whole, to fairly represent the nitrogen katabolism; that is, they satisfy the second of the two conditions above pointed out.

With these values for the protein katabolism were compared the nitrogen balances of periods of from two to four days (or in a few cases only one day) in which single foods were consumed along with sufficient carbohydrates and fat to fully supply the demands of the body for energy. The technic of these periods, however, can hardly be regarded as entirely satisfactory. Out of 33 days, the results of which are contained in his final table, the protein digested was greater than the average protein katabolism on the nitrogen-free days in 21 cases, the difference sometimes being considerable and sometimes relatively insignificant. As already pointed out, this tended to make the availability appear too low, and it is noteworthy that the excess of food protein is especially large in the experiments upon wheat flour which show a strikingly low availability. On the other hand, however, it is also true that a very low availability was found for maize protein in experiments in which but a slight excess was fed. In these experiments, however, the apparent digestibility of the protein was remarkably low, ranging from 56 to 69 per cent, but a similar low digestibility (about 68 per cent) was found in the trials with rice. Furthermore, the periods were relatively short and in many instances the nitrogen intake varied considerably within the period, so that it may be questioned whether the nitrogen excretion reached a stable value. Moreover, to some extent there was a more or less arbitrary selection of days to be compared. For all these reasons Thomas's results must be accepted with more or less reserve.

His final results for the percentage availability of the protein of different materials are as follows, the results being calculated in three different ways, viz:

A. Fecal nitrogen all regarded as derived from the food, that is, the comparison is made upon the basis of the apparently digested protein.

B. Fecal nitrogen regarded as being all present in the form of metabolic products.

C. One gram of fecal nitrogen is regarded as derived from metabolic products and the remainder from undigested food.

Relative availability of proteins—Thomas.

	A.	B.	C.
Lean beef	104.94	103.75	....
	106.51	105.73	....
Milk	99.65	99.71	....
Fish	103.09	102.06	....
	85.73	89.37	....
	88.17	91.95	....
Rice	83.00	88.53	87.09
	86.26	90.73	89.55
Crabs	72.60	78.85	....
	73.38	79.45	....
Yeast	56.63	73.48	69.58
	53.40	70.35	71.45
Casein	66.69	70.14	67.12
Nutrose	63.45	69.02	....
Wheat flour	29.17	36.25	....
	36.70	43.04	....
	64.50	42.04	....
	41.35	51.10	48.97
	27.74	39.75	36.94

Relative availability of proteins—Thomas—Continued.

	A.	B.	C.
Potatoes	56.37	....	68.80
	64.50	....	72.67
	73.00	....	78.72
	80.28	83.18	....
	77.04	....	76.22
	78.66	....	77.45
Cauliflower	80.68	....	87.78
	77.62	....	83.88
Spinach	64.50	....	68.83
Peas	49.58	59.89	55.15
	51.64	59.89	56.01
Cherries	66.42	....	78.57
Maize	24.55	....	40.47
	12.25	....	29.52
	....	....	3.54

In Zisterer's experiments, summarized on page 104, the feed nitrogen is so slightly in excess of the fasting nitrogen katabolism that it would seem that no large error would result from applying Thomas's method of computation. The results are as follows:

Percentage availability.

	Series I.	Series II.	Average.
Casein	82.26	83.77	83.02
Muscle protein	90.60	95.40	93.00
Wheat gluten	91.97	77.45	84.71

The results as thus computed are not widely different from those obtained by Thomas for casein and meat protein, but are slightly higher than his results for wheat protein. Michaud's results do not lend themselves to computation in this way.

Another recent investigation of a different character may be mentioned for the sake of completeness, viz, that on frogs by Busquet,[1] who compared lean veal and mutton with frog meat as regards the amount required to maintain the live weight or to produce a unit of gain of weight in previously fasting frogs. In this respect the veal and mutton were found distinctly inferior to the frog meat per unit of dry matter.

SIGNIFICANCE OF RESULTS.

In the comments upon the individual experiments, it has already been clearly indicated that they are open to criticism in many respects, such as the noncomparable nature of the protein supply, the lack of due consideration of the supply of mineral matter, etc. Moreover, nearly all the experiments were of relatively short duration.

Taking the results at their face value, however, they seem to indicate distinct differences in the nutritive values of proteins. The entire lack of certain groups, as in the case of gelatin and zein, seems to render impossible a complete substitution for tissue protein, while differences in the proportions of the different amino acids apparently result in differences in the replacement values of the proteins, although these differences, especially in the experiments of Michaud and Zisterer, are hardly as great as might have been expected. What now can be said regarding the probable significance of these differences for the ordinary problems of nutrition?

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[1] Journal de Physiologie et de Pathologie Générale, vol. 11, p. 399.

In the first place, it is to be remarked that both man and animals consume a mixture of proteins. The meat eater gets, along with his gelatin, the various muscle proteins. The animal fed on maize alone receives not only zein but its associated proteins, amounting, according to Osborne,[1] to about 40 per cent of the total protein of the grain, whose chemical constitution has not yet been reported. In the ordinary mixed rations of domestic animals it would appear that there must be a considerable degree of compensation between the different proteins as regards the proportions of the different cleavage products supplied to the organism, although it is difficult to judge to what extent this is the case. In view, however, of the rather small differences observed with pure proteins, it may be questioned whether such differences as exist in mixed rations are of very much significance.

In the second place, the observed differences in proteins were obtained in experiments in which small amounts of protein were consumed and in which the animals were on a low level of protein nutrition. As was pointed out in the discussion of those experiments, the consumption of protein in excess of the maintenance requirement, such as usually occurs with domestic animals, tends to obscure the differences between the proteins, owing to the considerable extent to which protein serves for fuel purposes under those conditions.

Third, almost all writers upon this subject tacitly assume the inability of the body to change one amino-acid into another. It does not appear that there is adequate proof of this inability. Most of the amino acids concerned belong to the aliphatic series of compounds, characterized by a straight carbon chain, and as between these compounds, at least, mutual changes are not difficult to conceive. As a matter of fact one such change appears to have been demonstrated. It is well known that when benzoic acid is consumed it is paired in the body with glycocol, forming hippuric acid which is excreted. It seems to be well established that with large amounts of benzoic acid more combined glycocol may appear in the excreta than can be assumed to have been present as such in the amount of protein katabolized during the same time. In this case, apparently, the body is able to manufacture glycocol from some other substance, presumably from the amino-acids containing a larger number of carbon atoms. Whether a change in the opposite direction, that is, a synthetic change, can take place can be at present only a matter of speculation, but such a change would be entirely analogous to the building up of the fatty-acid chains from carbohydrates, which is a common occurrence in the body. Moreover, Knoop,[1] and Embden and Schmitz[2] have found that certain amino acids may be formed synthetically from the corresponding fatty acids and ammonia, thus indicating a possible chemical mechanism by which a deficient supply of some one amino-acid might be to some extent overcome. While, therefore, we can hardly suppose that the proportions of the different cleavage products is a matter of entire indifference, we can easily imagine that there may be more or less transformation of one into another in case of need.

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[1] Journal of the American Chemical Society, vol. 19, p. 532.

Finally, there is the possibility that in the absence of some one amino-acid from the feed, the corresponding acid resulting from the katabolism of protein tissue may to a greater or less extent escape the action of the deamidizing enzyms and be regenerated to protein. This would obviously be quite in accord with the conception of the protein metabolism as a complex of reversible enzym reactions which was outlined on page 87.

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[1] Zeitschrift für Physiologische Chemie, vol. 67, p. 489.
[2] Biochemische Zeitschrift, vol. 29, p. 423.

Issued April 10, 1912.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 144.

A. D. MELVIN, CHIEF OF BUREAU.

INVESTIGATIONS RELATIVE TO ARSENICAL DIPS AS REMEDIES FOR CATTLE TICKS.

BY

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AND
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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., August 12, 1911.

Sir: I have the honor to transmit, and to recommend for publication in the bulletin series of this bureau, the manuscript of a paper entitled "Investigations Relative to Arsenical Dips as Remedies for Cattle Ticks," by Drs. B. H. Ransom and H. W. Graybill, of the Zoological Division.

One of the most important phases of the problem of dealing with the Texas fever tick is the finding of some effectual means of ridding cattle of the parasites. When large numbers of animals are concerned the most practical way of doing this is by dipping them in some substance that will destroy the ticks. A large variety of dips have been tried in this and other countries, but it has been difficult to find one that will kill the ticks without causing more or less injury to the cattle harboring them.

The experiments described in this bulletin indicate that arsenical dips, when properly compounded and used, furnish the best means yet devised for the purpose, as they are effective in destroying tho ticks and at the same time least objectionable in their effects upon the cattle.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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IV. Fig. 1.—Seven fully engorged and 17 partially engorged female ticks collected from a calf the next day after dipping in an arsenic and pine-tar solution. Fig. 2.—Engorged female tick collected from an undipped calf 16

V. Fig. 1.—Seven fully engorged and 10 partially engorged female ticks collected from a calf two days after dipping in an arsenic and pine-tar solution. Fig. 2.—Five fully engorged and three partially engorged female ticks collected from an undipped calf 18

VI. Fig. 1.—Fifty-one engorged female ticks after dipping in an arsenic and pine-tar solution. Fig. 2.—Forty engorged female ticks collected from an undipped calf 18

TEXT FIGURE.

Fig. 1. Plan of draining pen for cattle after dipping 65

INVESTIGATIONS RELATIVE TO ARSENICAL DIPS AS REMEDIES FOR CATTLE TICKS.

INTRODUCTION.

It is now a well-known fact that the Texas-fever tick may be eradicated from cattle and pastures by following a certain course of procedure in which the cattle are moved from time to time from one pasture to another; in other words, eradication may be accomplished by so-called "rotation methods" without the necessity of treating the cattle with tick-killing substances. In many instances, however, it is impracticable, uneconomical, or on some other account undesirable to depend upon the automatic eradication which ultimately takes place when proper rotation methods are followed. Therefore it becomes necessary in such cases either to use them in connection with other methods or to resort to other methods alone. The dipping or spraying of cattle with a substance destructive to ticks provides a means of hastening eradication and of rendering it possible in the presence of conditions under which unmodified rotation methods would be practically out of the question.

Ever since the fact that the tick is the agent of transmission of Texas fever was established, investigations have been carried on under the auspices of the Bureau of Animal Industry, State agricultural experiment stations, and other institutions for the purpose of discovering some substance which, when applied externally to the bodies of tick-infested cattle, would free them from ticks without injury to the animals themselves. Very early in the history of these investigations it was found that ticks were highly resistant to treatment, and it has been determined that several remedies which give good results in the case of such external parasites as mange mites and lice are of little or no use in the case of ticks. Some substances appeared to have absolutely no effect and others, when applied at a sufficient strength to destroy the ticks, were so severe in their effects upon the cattle that they could not be used in practice. For example, lime-and-sulphur, tobacco, and coal-tar dips, which are very satisfactory remedies against certain other external parasites of cattle, have been found to have no practical value in the destruction of ticks. Oil dips have proved more successful, and for several years crude petroleum, provided it conformed to certain requirements as to its physical and chemical characteristics, has been recognized by the live-stock sanitary authorities of the Federal Government and of various States as an efficacious remedy against cattle ticks. However, although the efficacy of crude petroleum is generally admitted, there are a number of more or less serious objections to it which have largely interfered with its usefulness. Among these objections may be mentioned the facts that in practice crude petroleum of proper composition is difficult to procure, is rather expensive, bulky, liable to loss by leakage, is frequently very severe in its effects upon cattle, and produces a greasy condition of the hair and skin which is highly undesirable in the case of dairy cattle.

About six years ago the Bureau of Animal Industry began investigating arsenical solutions with reference to their utility for dipping cattle to free them from ticks. At that time arsenical dips as remedies against ticks had been considerably used in South Africa, and to some extent in Australia and South America, but practically not at all in the United States. In 1906, following the publication of two articles[1] by Dr. N. S. Mayo, at that time chief veterinarian of Cuba, in which an arsenical solution was highly recommended as both efficacious against ticks and noninjurious to cattle, a number of trials of arsenical solutions were made in Texas, at first under cooperation between the Bureau of Animal Industry and the live-stock sanitary commission of Texas and later by the Bureau of Animal Industry working alone. The composition and method of preparing the arsenical solution as described by Mayo, in the first article referred to, are as follows:

White arsenic	1½ pounds.
Sodium carbonate, crystals	4½ pounds.
Yellow soap	4½ pounds.
Pine tar	1 quart.
Water	100 gallons.

The arsenic is to be dissolved in 5 or more gallons of water by boiling for one-half hour; when dissolved add it to 20 gallons of water. Shave the soap, mix with the soda and dissolve in 5 gallons of water. When dissolved, add the tar in a fine stream and stir until the tar is in solution, then mix with the arsenical solution and add sufficient water to make 100 gallons.

In the second article referred to, which appeared about a month later, Mayo gave a somewhat different formula, but essentially the same method for preparing the arsenical dip, as follows:

Arsenious acid	8 pounds.
Soda carbonate, crystals	24 pounds.
Yellow soap	24 pounds.
Pine tar	1 gallon.
Water	500 gallons.

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[1] Breeder's Gazette, vol. 49, No. 11, p. 564, and American Veterinary Review, vol. 30, No. 2, pp. 243-245.

Dissolve the arsenic in 20 gallons or more of water by boiling for 30 to 40 minutes. When dissolved, add to 100 gallons of water. Dissolve the soap and soda in 20 gallons of boiling water, first shaving the soap, and while boiling add the pine tar in a thin stream and stir until it is dissolved. Mix this with the arsenical solution and add sufficient water to make 500 gallons.

In the course of the first year's trials of the dip in Texas Dr. Mayo's formula was slightly modified by the omission of the soap, which did not seem to add to the efficacy of the dip. The formula and method of preparation which were usually employed were as follows:

White arsenic	8 pounds.
Sodium carbonate	24 pounds.
Pine tar	1 gallon.
Water sufficient to make	500 gallons.

The arsenic and sodium carbonate were dissolved by boiling in 25 or 30 gallons of water, after which the fire was drawn and the solution allowed to cool somewhat. The tar was then added, and finally the mixture was added to sufficient water to make 500 gallons of dip.

During 1906 about 12,000 head of cattle were treated in Texas with the arsenical dip under the supervision of inspectors or agents of the Bureau of Animal Industry with results which in some respects were highly encouraging. Though it appeared questionable from the reports of these dippings whether the dip was absolutely efficacious, there seemed to be no doubt as to its highly destructive action on ticks and, as compared with crude petroleum, its slight injurious effects upon cattle. In fact, the apparent merits of the dip were such that its use was enthusiastically adopted by cattle owners in Texas and has been continued up to the present time, the range of popularity of the dip increasing from year to year.

In consequence of the promising results secured in the first trials of the arsenical solution, the Bureau of Animal Industry has carried out a number of investigations and experiments in order to obtain definite data relative to the efficacy of arsenical solutions as remedies against ticks.

COMPOSITION OF THE DIPS USED IN THE EXPERIMENTAL WORK.

In most of the experiments the arsenical solution used was compounded in accordance with the modification of Dr. Mayo's formula given above, the amounts of arsenic varying from 8 to 12 pounds, and of sal soda from 24 to 45 pounds, for each 500 gallons of dip, in different instances. When pine tar was used it was added in the proportion of 1 gallon to each 500 gallons of dip. In some of the experiments arsenical dips of somewhat different composition were used. The amount of arsenic in solution in the various dips, expressed in its equivalent of arsenic trioxid, varied from 0.16 to 0.495 per cent.

In the Mayo dip and its modifications the arsenic is present in the form of a sodium salt known as sodium arsenite, which results from the chemical reaction which takes place between the arsenic (arsenic trioxid) and the sal soda (sodium carbonate) when these substances are boiled together. It has been found by Aubrey V. Fuller,[1] of the Biochemic Division of this bureau, that under certain conditions the sodium arsenite in an arsenical dip becomes more or less completely oxidized to sodium arsenate, this change occurring after the lapse of several weeks, a fact of great practical importance, since sodium arsenate seems to be weaker in its action upon ticks than is sodium arsenite.

In the experiments recorded in the present paper the arsenic in the dips used was in solution as arsenite unless otherwise stated, and was known so to be either because the dips were used fresh or because the dips were afterwards proved by chemical analysis to be unoxidized.

The proportionate amount of sal soda used in the arsenic, sal soda, and pine-tar mixture is more than is necessary to transform the arsenic into sodium arsenite. It has not been determined whether a dip containing an excess of soda is more efficacious than one in which just enough soda has been used to complete the reaction with the arsenic. In view of the fact, however, that the cuticle of ticks is softened and may be dissolved by alkaline solutions, it is possible that the efficacy of the dip may depend in part upon the weak alkalinity given to it by the excess of soda used in its preparation. The function of the pine tar in the dip is indefinitely known. Whether it actually renders the dip more efficacious is uncertain. It does, however, give body to the dip, and also serves the useful purpose of rendering the appearance and odor of the dip distinctive.

DETAILS OF THE EXPERIMENTS.

ARSENIC, SODA, AND PINE-TAR DIPS.

Experiment No. 1.

Twelve head of cattle, most of them moderately or heavily infested with ticks, were dipped October 13, 1907, near Quanah, Tex., in an arsenic, soda, pine-tar dip containing an equivalent of 0.204 per cent arsenic trioxid.[2] The dip was prepared from 20 pounds of commercial arsenic (96.18 per cent arsenic trioxid[2]), 60 pounds of sal soda, 2 gallons of pine tar, and 1,075 gallons of water. The quantity of water was determined from arithmetical calculations based upon measurements of the dimensions of the vat. The vat was about 20 feet in length at the surface of the dip, and the cattle when dipped were immersed from 5 to 10 seconds.

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[1] Bureau of Animal Industry Circular 182.

[2] Analysis made in Biochemic Division.

The cattle suffered no evident injury to the skin as a result of dipping. Seven days after dipping they were nearly free from ticks, the ticks present being partially grown females, males, and nymphs. Of six engorged ticks which dropped from the cattle immediately after dipping, 4 died without depositing eggs, the other 2 depositing a few eggs, none of which hatched. Two days after dipping 14 engorged ticks were collected, 5 of which died without depositing eggs. The other 9 deposited a few eggs, none of which hatched. Eight engorged ticks collected October 12 from undipped cattle, and kept under the same conditions as those from the dipped cattle, all deposited a normal number of eggs, nearly all of which hatched. Four nymphs were collected two days after dipping. One afterwards molted, 1 died in course of molting, and 2 failed to molt. Seven days after dipping 13 nymphs were collected. One of these afterwards molted, and 12 failed to molt. Fourteen nymphs were collected from an undipped cow October 15 and kept under the same conditions as those from the dipped cattle. Ten of these afterwards molted, 1 died while molting, and 3 failed to molt.

Experiment No. 1a.

October 16, three days after the first dipping, a heavily infested cow was redipped, after the addition of 4 pounds of arsenic and 12 pounds of soda, previously boiled together, to the dip already in the vat. No analysis was made of this strengthened dip, but the amount of arsenic may be estimated as equivalent to about 0.24 per cent arsenic trioxid.

October 20, four days after the second dipping and seven days after the first dipping, there was no apparent injury to the skin. Nearly all the ticks were dead. Those remaining alive were females one-half to fully grown, most of them showing distinct evidences of having been injured by the dip. Twenty-five engorged ticks were collected from the cow in this experiment four days after the second dipping; 19 of these died within 24 hours; 2 of the remaining 6 afterward deposited a few eggs, none of which hatched. The other 4 died without depositing eggs. Fourteen engorged ticks collected from undipped cattle October 22 and kept under the same conditions as those from the dipped cow deposited numerous eggs, most of which hatched. Another lot of 6 engorged ticks collected on the same date from undipped cattle deposited about 1,000 eggs, about 100 of which hatched.

Experiment No. 2.

Two cattle heavily infested with ticks were sprayed in a spraying machine October 22, 1907, near Vernon, Tex., with an arsenic, soda, and pine-tar dip containing an equivalent of 0.172 per cent arsenic trioxid.[1] The dip was prepared from 10 pounds of commercial arsenic (99.56 per cent arsenic trioxid [1]), 24 pounds of sal soda, 1 gallon of pine tar, and 500 gallons of water (measured in barrels). The cattle were held in the spraying machine for about 10 seconds. Owing to the faulty working of the machine, the application of the dip was not as thorough as it might have been had the machine worked properly.

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[1] Analysis made in Biochemic Division.

The skin injury as a result of spraying was very slight, and the evidences of injury had practically disappeared eight days after the treatment. Five days after spraying the skin of one of the animals was somewhat thickened between the hind legs and on the neck where the ticks had been numerous, and the skin on the neck of the other animal where the ticks had been particularly numerous was very slightly thickened and cracked. The cattle were nearly free from ticks eight days after spraying, the ticks present being partially grown females, males, and nymphs. Eight engorged ticks were collected from the cattle 16 hours after spraying. One of these died without depositing eggs; the other 7 laid relatively few eggs, none of which hatched. Of 5 engorged ticks collected five days after spraying, 4 died without depositing eggs; the other one laid about 200 eggs, none of which hatched. Fourteen engorged ticks collected October 22 from untreated cattle and kept under the same conditions as those from the sprayed cattle deposited numerous eggs, most of which hatched, and another lot of 6 engorged ticks collected on the same date from untreated cattle deposited about 1,000 eggs, about 100 of which hatched. Seven nymphs collected 16 hours after spraying failed to molt. Sixty-nine nymphs collected five days after spraying failed to molt. Seven nymphs collected eight days after spraying failed to molt. Twenty-five nymphs were removed from untreated cattle October 22 and were afterwards kept under the same conditions as those from the sprayed cattle. All but 4 of these molted.

Experiment No. 3.

Three cattle heavily infested with ticks and two cattle lightly infested were sprayed July 11, 1908, near Purcell, Okla., with an arsenic, sal soda, and pine-tar dip containing an equivalent of not more than 0.217 per cent arsenic trioxid. The dip was prepared from 3 pounds of commercial arsenic (99.05 per cent arsenic trioxid[1]), 15 pounds of sal soda, 0.3 gallon of pine tar, and 165 gallons of water. The same spraying machine was used that was used in Experiment No. 2. The cattle were not held in the machine, but were allowed to pass through as rapidly as they would.

The skin of these cattle was only very slightly injured. Five days after treatment 3 of the cattle were nearly free from ticks; the other 2 could not be found on this date. The live ticks present were 2 engorged females, a few partially grown females, 1 male, and a considerable number of nymphs, which were apparently still alive.

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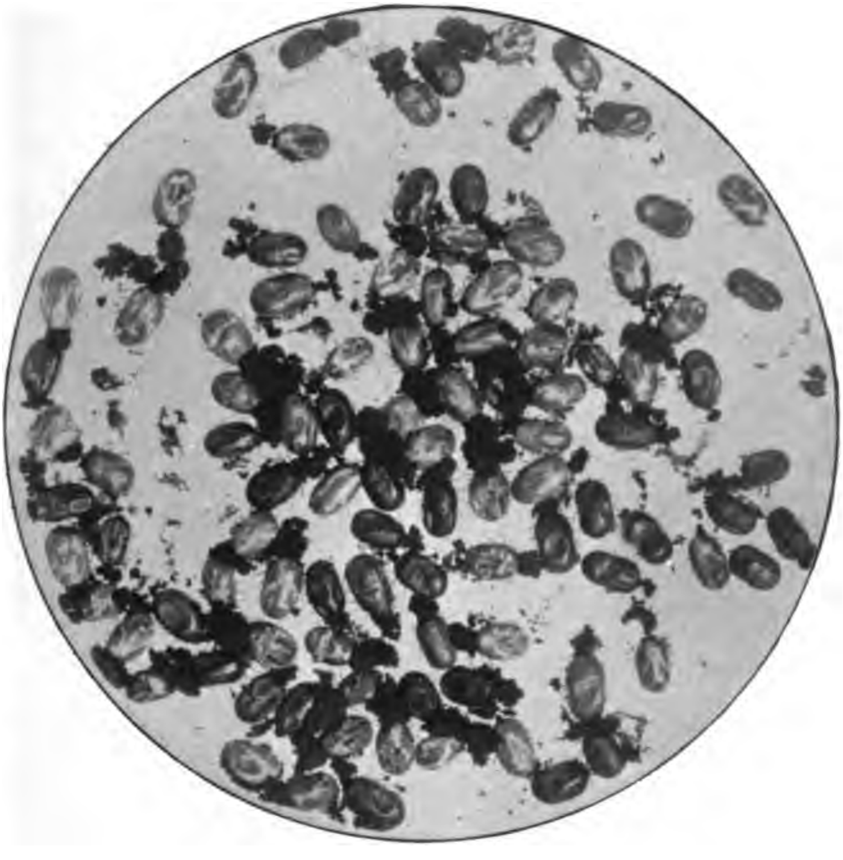
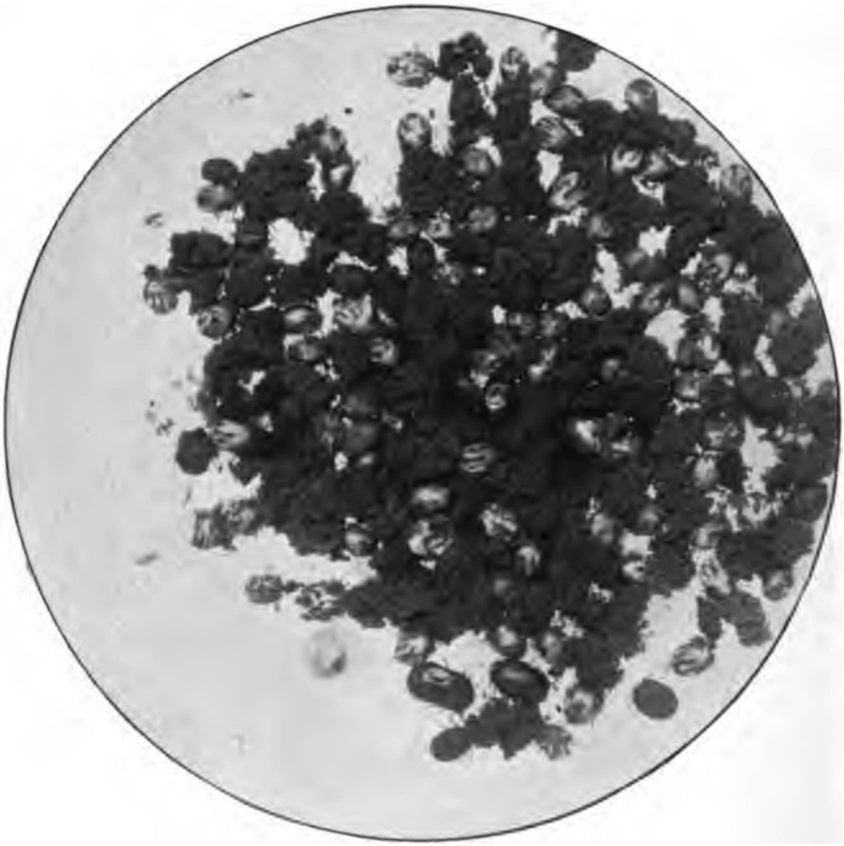
[1] Analysis made in Biochemic Division.



DIPPED TICKS.

Experiment No. 4. One hundred and twenty-three engorged female ticks after dipping in an arsenical solution containing an equivalent of less than 0.22 per cent arsenic trioxid. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 23.4 milligrams, and none of them hatched. Two-thirds natural size; from a photograph taken 24 days after dipping. Compare Plate II, showing untreated ticks collected on the same date as those shown in this plate.



UNDIPPED TICKS.

Experiment No. 4. One hundred and five engorged female ticks collected on the same date as those shown in Plate I, and kept under the same conditions, but not dipped. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 127.5 milligrams, and practically all of them hatched. Two-thirds natural size; from a photograph taken on the same date as that of the ticks shown in Plate I.

Fifteen engorged females were removed from the cattle immediately after spraying. All of these died without depositing eggs.

For comparison it may be noted, in the absence of any data as to engorged ticks from untreated cattle on July 11, that engorged ticks (number not recorded) collected July 11 from cattle sprayed July 8 with an emulsion of crude petroleum and liquor cresolis compositus containing about 5 per cent crude petroleum and about 1 per cent cresylic acid, deposited a normal number of eggs, many of which hatched. These ticks were kept, after their removal from the cattle, under the same conditions as those from the cattle sprayed with the arsenical dip. Six nymphs were collected immediately after spraying from the cattle sprayed with arsenical dip, and 2 of these molted. Four nymphs were collected on the same date from the cattle sprayed three days before with the oil and cresol emulsion, and were kept after collection under the same conditions as those from the cattle sprayed with the arsenical dip; all but one of them molted.

Experiment No. 4.

August 7, 1908, 228 fully engorged ticks were collected from some infested cattle at the Bureau Experiment Station, Bethesda, Md. On August 8, 123 of these ticks were immersed in an arsenical solution containing an equivalent of not more than 0.213 per cent arsenic trioxid. They remained in the solution two minutes, were then removed and dried by means of filter paper, after which they were placed in a large Petri dish under a bell jar under which was also placed an open vessel of water. The arsenical solution was prepared from 1 gram of arsenic trioxid, 3 grams of sodium carbonate, and 465 c. c. of water. No pine tar was added to the solution. Twenty-two of the ticks died without depositing eggs. The remainder deposited eggs whose aggregate weight equaled 2.876 grams. Oviposition was completed September 1 (see Pl. I, from a photograph taken on this date). None of the eggs hatched.

August 8 the remainder of the ticks collected the day before, 105 in number, were placed in a Petri dish under the same bell jar as those which were immersed in arsenical solution and kept thereafter under the same conditions as the latter. All of the untreated ticks deposited eggs whose aggregate weight amounted to 13.394 grams, nearly 5 times the weight of the eggs from the dipped ticks.[1] Oviposition was completed September 1 (see Pl. II, from a photograph taken on this date). Practically all of the eggs from the untreated ticks afterwards hatched.

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[1] It is to be noted here and hereafter in this paper that when a comparison by weight is made between the eggs laid by ticks that have been dipped and the eggs in the corresponding control lot, the difference is somewhat emphasized, due to the fact that the eggs from dipped ticks commonly become more or less shriveled, and hence weigh somewhat less than the same number of normal eggs.

Experiment No. 5.

During several weeks in the late summer and early fall of the year 1908, larval ticks were applied every other day to three calves at the Bureau Experiment Station, Bethesda, Md. On October 12 numerous ticks of all ages, from newly attached larvæ to fully engorged females, were present on each of these animals. An arsenic, sal soda, and pine-tar dip was prepared which contained an equivalent of 0.16 per cent arsenic trioxid.[1] On the above-mentioned date one of the calves (No. 582) was dipped in the arsenical dip and was kept in the bath two minutes. After dipping this calf was placed in a noninfested pen. Beginning immediately after dipping, all female ticks, so far as possible, were collected every day as they reached the stage of full engorgement. These ticks were brought to the laboratory and kept in Petri dishes. All but a very few of the ticks which matured were collected. Those which matured during the night of course escaped, except those found in the morning crawling on the floor of the pen.

During the first week after dipping, October 12 to 18, inclusive, 1,340 engorged ticks were collected from calf No. 582. The eggs of 291 of these ticks, comprising some individuals from each day's collection, amounted in weight to 5.57 + grams, an average of 0.019 gram per tick. Applying this average to the entire 1,340 ticks, the total weight of eggs may be assumed to be 25.46 grams. By calculation from the records which were kept of the percentage of eggs hatching from the ticks of each day's collection, the eggs which hatched were found to correspond to a weight of 0.178 + gram, or 0.7 per cent of all the eggs deposited by the ticks maturing the first week after dipping, which corresponds to an average of 0.000133 gram per tick. Subsequent to October 18, ticks continued to mature on calf No. 582 until November 9, four weeks after dipping, the total number maturing during this time being 67.

Calf No. 583 was dipped October 12 in the arsenic, soda, and pine-tar dip after 0.5 per cent (by weight) glycerin was added. The period of immersion in the bath was 1½ minutes. After dipping, the calf was placed in a noninfested pen. The same procedure with regard to the collection of engorged ticks was followed as in the case of the other calf. During the first week after dipping, from October 12 to 18, inclusive, 1,907 engorged ticks were collected from calf No. 583, and the eggs of 599 of these ticks amounted in weight to 10.2 + grams, an average of 0.017 gram per tick. Assuming that each of the entire number (1,907) collected averaged the same amount of eggs deposited, the entire weight of eggs may be estimated at 32.4 + grams. The number hatching, as calculated from the records kept of the percentage which hatched from the ticks of each day's collection, corresponds to a weight of 0.325 gram, which is 1 per cent of the total quantity of eggs laid, or an average of 0.00017 gram per tick. The last tick to mature on calf No. 583 was collected on November 7, up to which time and subsequent to October 18, 37 female ticks reached the engorged condition.

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[1] Analysis made in Biochemic Division.

Calf No. 584, the undipped animal, was put in a noninfested pen October 12 and no more larvæ placed on it. The ticks which matured were collected every day, and some of these were placed in Petri dishes and kept under the same conditions as the ticks from the 2 dipped animals. October 12 to 18, inclusive, the number of engorged ticks collected from calf No. 584, of which a record was kept, was 968. The weight of the eggs deposited by 358 of these was 25.54+ grams, an average of 0.071 gram per tick. This average is about four times greater than the averages of the ticks from the 2 dipped calves. On the basis of an average of 0.071 gram of eggs per tick the total number of eggs deposited by the recorded ticks collected from calf No. 584 October 12 to 18 may be estimated as corresponding to a weight of 68.7+ grams. The number which hatched, as calculated from the records kept of the percentage which hatched from the ticks of each day's collection, corresponds to a weight of 55.59 grams, which is 80 per cent of the weight of the entire number of eggs deposited, or 0.0568 gram per tick.

Assuming 0.04 milligram to be the average weight of a single egg, the average number of larvæ produced by each tick maturing on calf No. 584, the undipped animal, as calculated from the foregoing data, was 1,400, whereas the number of larvæ produced by the ticks maturing on the other calves during the first week after dipping averaged, as determined by a similar calculation, only 3.2 for each tick maturing on calf No. 582 and 4.2 for each tick maturing on calf No. 583. Ticks continued to mature on calf No. 584 until November 18, and during the period from October 19 to November 9 (the latter date being the last day on which any ticks matured on either of the dipped animals) 1,029 ticks were recorded as maturing on this animal, in comparison with which it should be noted that only 67 and 37 ticks, respectively, matured on the 2 dipped cattle subsequent to October 18.

From the foregoing it is evident that the 2 dipped calves became almost free from ticks within a week after dipping, only 67 in one case and 37 in the other, which afterwards matured, being present at the end of this time, a marked contrast to the fact that more than 1,029 ticks that afterwards matured were still present on the undipped calf a week after removal from further infestation.

No injury to the skin from dipping was noted other than a very slight dandruff-like exfoliation. The addition of the glycerin to the dip in which the second calf was dipped had no apparent effect on the action of the dip.

Experiment No. 6.

On August 13, 1909, a calf which had been artificially infested with ticks, and which at the time of dipping harbored ticks in all stages of development, was dipped at the Bureau Experiment Station in an arsenic, sal soda, and pine-tar dip containing an equivalent of 0.215 per cent arsenic trioxid.[1] The dip was prepared from 7 pounds of arsenic trioxid, 21 pounds of sodium carbonate (crystallized), 0.7 gallon of pine tar, and about 350 gallons of water. The calf remained in the bath two minutes. After dipping, the calf was kept in a tick-infested pen until August 20, seven days after the first dipping, when it was redipped in the dip which had been left in the vat since the first dipping. The calf was kept in the bath two minutes at the second dipping, and then removed to a non-infested pen. Beginning immediately after the first dipping the female ticks were collected as they reached the engorged condition.

The skin of the calf was very slightly affected by the dipping, became somewhat thickened in places on the neck and thighs, and some exfoliation occurred. When the animal was discharged from the experiment September 9 the skin was in excellent condition, soft, pliable, and very sleek.

Five days after the first dipping a few newly molted adult ticks and a few partially engorged females were found to be alive. The latter were abnormally swollen as a result of arsenical poisoning. Nymphs apparently alive were rather numerous. Seven days after the first dipping most of these were certainly dead. A few newly molted adults were found to be alive, and partially grown females, abnormally swollen, were still present. No live larvæ were found on either the fifth or seventh day. Eight days after the first dipping no live ticks in any stage of development were found, nor were any found subsequently.

August 13, immediately after dipping, 57 engorged and nearly engorged female ticks were collected from the calf, all but 18 of which died without depositing eggs. These 18 ticks deposited eggs whose aggregate weight amounted to 0.077 gram, and none of these hatched. (See Pl. III, fig. 1, from a photograph taken Aug. 31.) Later in the day, August 13, 27 engorged females were collected, 17 of which died without depositing eggs. The other 10 deposited eggs aggregating 0.1008 gram in weight, none of which hatched.

In comparison note that 17 engorged females collected August 13 from an undipped calf and kept under the same conditions as those from the dipped calf all deposited eggs weighing 0.8953 gram, 97

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[1] Analysis made in Biochemic Division.

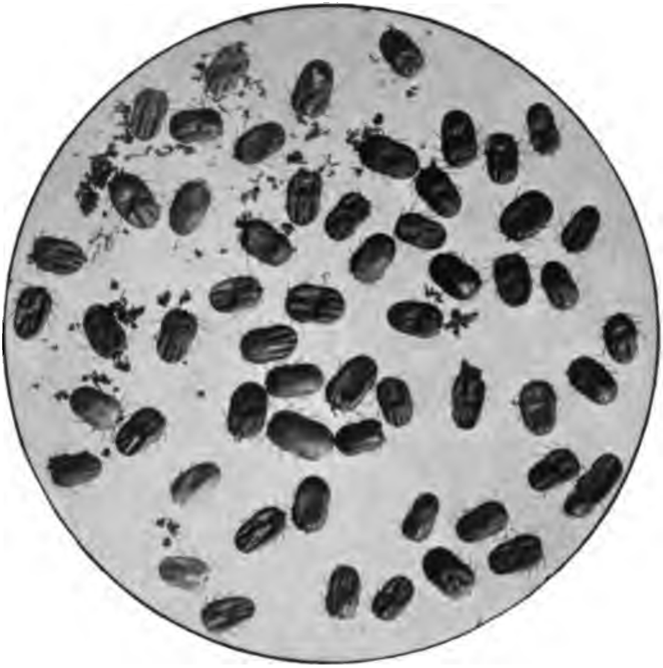

FIG. 1.—DIPPED TICKS.

Experiment No. 6. Fifty-seven engorged and nearly engorged female ticks collected from a calf immediately after dipping in an arsenic and pine-tar solution containing an equivalent of 0.215 per cent arsenic trioxid. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 1.3 milligrams, and none of them hatched. Natural size; from a photograph taken 18 days after collection.

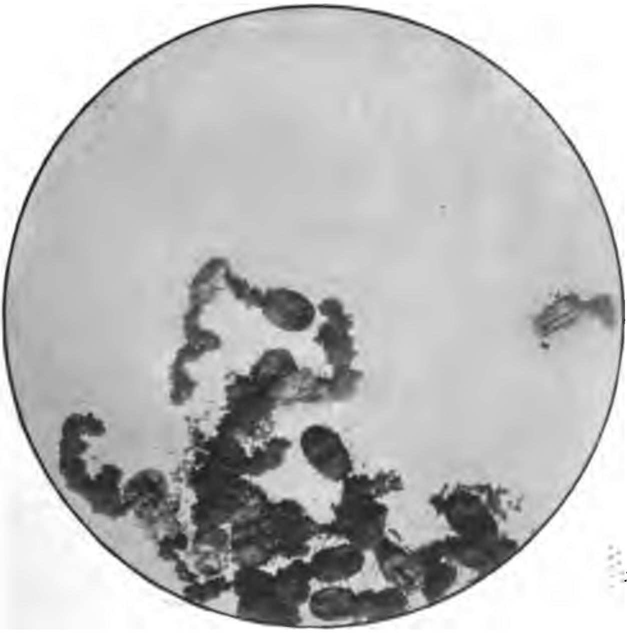

FIG. 2.—UNDIPPED TICKS.

Experiment No. 6. Seventeen engorged female ticks collected from an undipped calf on the same date as those shown in Fig. 1, and kept under the same conditions. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 52.7 milligrams, and 97 per cent of them hatched. Natural size; from a photograph taken 18 days after collection.

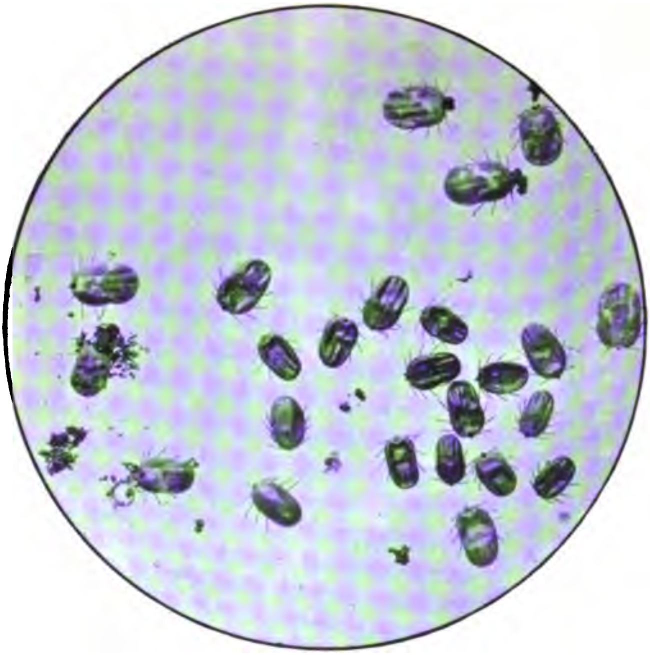

FIG. 1.—DIPPED TICKS.

Experiment No. 6. Seven fully engorged and seventeen partially engorged female ticks collected from a calf the next day after dipping in an arsenic and pine-tar solution containing an equivalent of 0.215 per cent arsenic trioxid. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 2.1 milligrams, and none of them hatched. Natural size; from a photograph taken 17 days after collection.

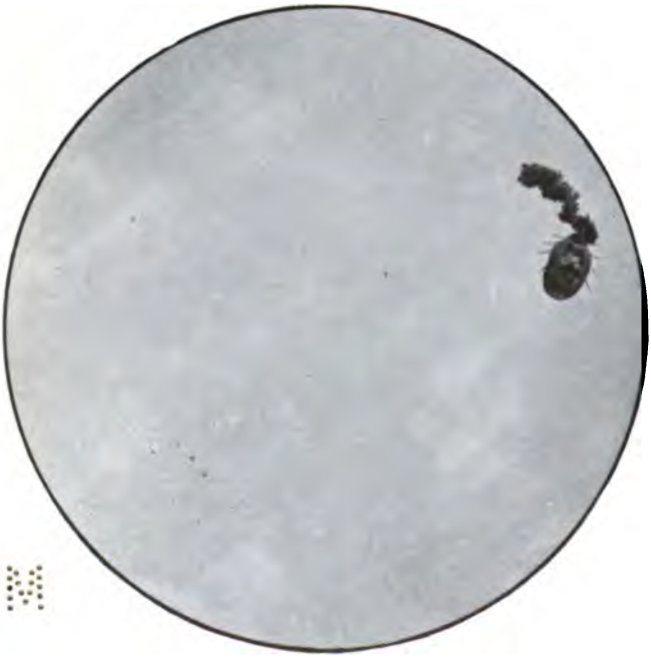

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FIG. 2.—UNDIPPED TICK.

Experiment No. 6. Collected from an undipped calf one day earlier than those shown in Fig. 1, and kept under the same conditions. The weight of eggs deposited by this tick was 42.6 milligrams, and 40 per cent of them hatched. Natural size; from a photograph taken 18 days after collection.

per cent of which hatched. (See Pl. III, fig. 2, from a photograph taken Aug. 31.) Note also that one engorged female collected August 13 from an undipped calf and kept under the same conditions as the ticks from the dipped calf deposited eggs weighing 0.0426 gram, 40 per cent of which hatched. (See Pl. IV, fig. 2, from a photograph taken Aug. 31.)

August 14, 24 ticks were collected, 7 of which were fully engorged, the others partially engorged. Five of these laid eggs weighing 0.0512 gram. The others died without laying eggs. None of the eggs hatched. (See Pl. IV, fig. 1, from a photograph taken Aug. 31.) No ticks were collected on this date from undipped cattle, but it may be noted that ticks, already referred to, which were collected from undipped cattle the day before and were kept under the same conditions as those from the dipped calf deposited numerous eggs, a large proportion of which hatched. (See Pl. IV, fig. 2, and Pl. III, fig. 2, from photographs taken Aug. 31.)

August 15, 17 ticks (7 fully engorged and 10 partially engorged) were collected. Thirteen of these died without laying eggs. The other 4 laid eggs aggregating 0.05 gram in weight, none of which hatched. (See Pl. V, fig. 1, from a photograph taken Aug. 31.) No ticks were collected from undipped cattle on this date, but the lot of ticks just discussed may be compared with a lot of 8 females (5 fully engorged and 3 partially engorged) collected from an undipped calf the following day, August 16. These were kept under the same conditions as the ticks from the dipped calf, and all of them deposited eggs aggregating 0.4686 gram in weight, 99 per cent of which hatched. (See Pl. V, fig. 2, from a photograph taken Aug. 31.)

August 16, 9 ticks (5 fully engorged and 4 nearly engorged) were collected, 2 of which died without laying eggs. The other 7 laid eggs aggregating 0.1713 gram in weight, none of which hatched.

In comparison note that 8 ticks (5 fully engorged and 3 partially engorged) collected from an undipped calf August 16 and kept under the same conditions as the ticks from the dipped calf, all deposited eggs weighing 0.4686 gram, 99 per cent of which hatched.

August 17, four days after the first dipping and the last day on which any ticks matured on the calf in this experiment, 1 engorged female was collected. This tick deposited eggs weighing 0.056 gram, and 50 per cent of them hatched. A tick collected from an undipped calf on the same date, and kept under the same conditions as the ticks from the dipped calf, deposited eggs weighing 0.0715 gram, 98 per cent of which hatched.

Experiment No. 7.

August 17, 1909, 15 engorged ticks collected the day before from undipped cattle at the Bureau Experiment Station were immersed in some of the dip used in Experiment No. 6, which contained an equivalent of 0.215 per cent arsenic trioxid. The ticks remained in the dip two minutes, were then removed, dried on filter paper, placed in a Petri dish, and kept under observation in the laboratory. Two of these survived until August 30, but none laid any eggs. Eight engorged ticks, which were collected on the same day as the ticks just referred to and kept under the same conditions except that they were not dipped, all deposited eggs whose aggregate weight equaled 0.4686 gram. Ninety-nine per cent of these eggs hatched.

August 27, another lot of ticks, consisting of 51 engorged females collected August 25, were dipped in some of the same dip and were handled and kept under the same conditions as those discussed in the preceding paragraph. All of these died without laying eggs. (See Pl. VI, fig. 1, from a photograph taken Aug. 31.) Another lot of 40 females, collected August 25 and kept under the same conditions except that they were not dipped, all deposited eggs whose aggregate weight amounted to 2.1371 grams, and 60 per cent of these eggs hatched. (See Pl. VI, fig. 2, from a photograph taken Aug. 31, before oviposition was entirely completed.)

Experiment No. 8.

On August 26, 1909, a tick-infested calf was dipped in the arsenical dip used in Experiment No. 6, which had remained in the vat at the Bureau Experiment Station since August 13. This dip originally contained an equivalent of 0.215 per cent arsenic trioxid, but analysis of a sample taken September 2 showed an equivalent of 0.234 per cent arsenic trioxid. It is assumed that the dip had meanwhile lost sufficient water by evaporation to cause this increase in the percentage of arsenic. When used August 26 the dip therefore contained an equivalent of between 0.215 and 0.234 per cent arsenic trioxid.

The calf used in this experiment had been artificially infested with ticks by applying larvæ every other day for several weeks prior to dipping. When the animal was dipped numerous ticks in all stages of development were present. The period of immersion in the bath was two minutes. After dipping, the calf was put into a tick-infested inclosure, and larval ticks were applied every other day until September 2, when a second dipping was given. Before the animal was dipped the second time about 50 gallons of water were added to the dip in the vat. Analysis of a sample taken from the vat after the addition of the water showed that it contained an equivalent of

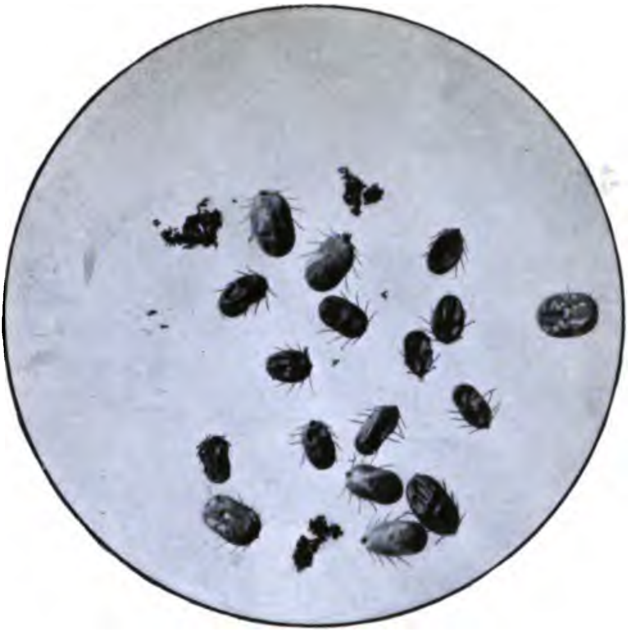

FIG. 1.—DIPPED TICKS.

Experiment No. 6. Seven fully engorged and ten partially engorged female ticks collected from a calf two days after dipping in an arsenic and pine-tar solution containing an equivalent of 0.215 per cent arsenic trioxid. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 3 milligrams, and none of them hatched. Natural size; from a photograph taken 16 days after collection.

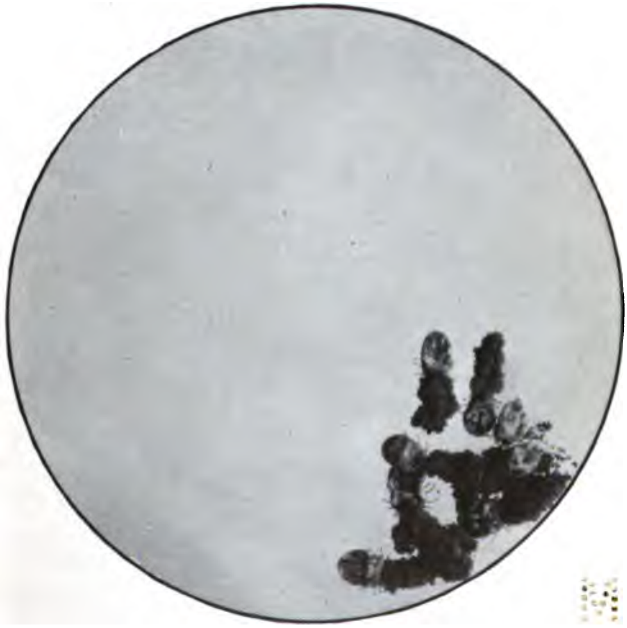

FIG. 2.—UNDIPPED TICKS.

Experiment No. 6. Five fully engorged and three partially engorged female ticks collected from an undipped calf one day later than those shown in Fig. 1, and kept under the same conditions. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 58.6 milligrams, and 99 per cent of them hatched. Natural size; from a photograph taken 15 days after collection.

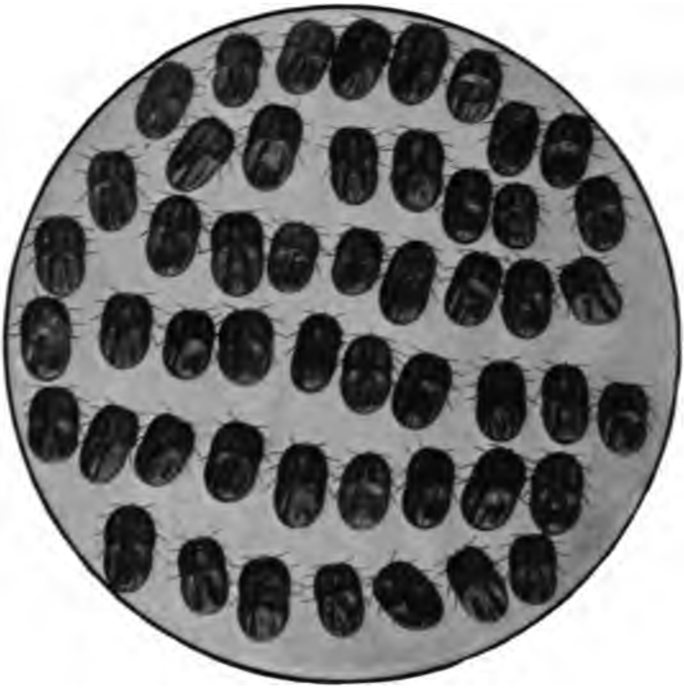

Fig. 1.—Dipped Ticks.

Experiment No. 7. Fifty-one engorged female ticks after dipping in an arsenic and pine-tar solution containing an equivalent of 0.215 per cent arsenic trioxid. All of them died without depositing eggs. Natural size; from a photograph taken 4 days after dipping.

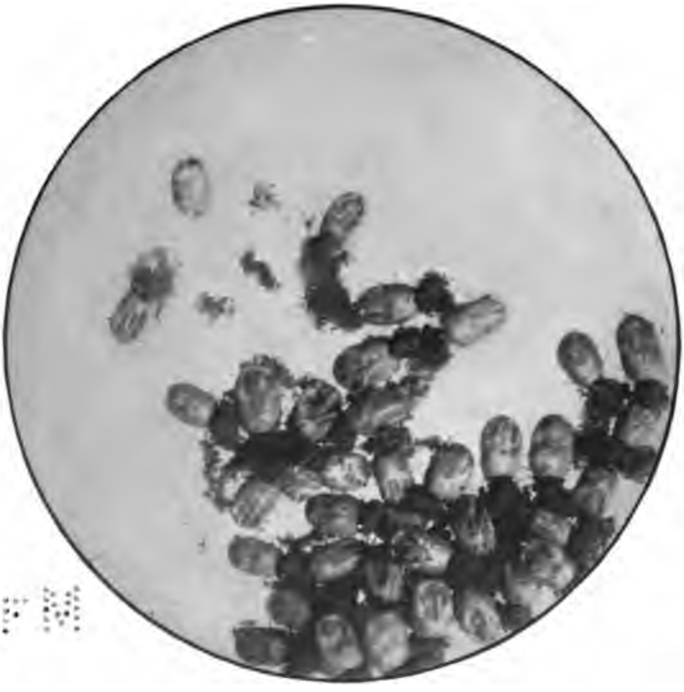

Fig. 2.—Undipped Ticks.

Experiment No. 7. Forty engorged female ticks collected from an undipped calf on the same date as those shown in Fig. 1, and kept under the same conditions, but not dipped. The average weight of eggs per tick deposited by this lot (including all ticks whether they oviposited or not) was 53.4 milligrams, and 60 per cent of them hatched. Natural size; from a photograph taken on the same date as that of the ticks shown in Fig. 1.

0.196 per cent arsenic trioxid. The period of immersion at the second dipping was two minutes. After this dipping the calf was removed to a noninfested yard. August 28, two days after the first dipping, no injury to the skin was yet apparent. September 2 the skin was slightly sore on the escutcheon and on the vulva, near the tail. There was a slight exfoliation on the inner side of the forelegs. On September 9, seven days after the second dipping, there was noted a very slight exfoliation, and the skin was very slightly irritated on escutcheon, inguinal region, axillæ, inner side of forelegs, and around anus. A few days later all signs of skin injury had disappeared.

August 28, two days after the first dipping, a considerable number of adult ticks in various stages of growth were alive, many of them, however, evidently affected by the arsenic. Some nymphs were apparently alive. No ticks matured subsequent to August 29, three days after the first dipping. September 2 no live ticks were found, except some nymphs which were apparently alive. September 9, one week after the second dipping, the calf was entirely free from ticks.

August 26, immediately after the first dipping, 46 engorged female ticks were collected from the calf. All of these but one died without laying eggs. This one deposited about 30 eggs, none of which hatched. Later on the same day 6 engorged females were collected, 3 of which died without laying eggs. The other 3 laid eggs weighing 0.0874 gram, none of which hatched.

In comparison with the above it may be noted that 40 engorged females collected from an undipped calf August 25, and kept under the same conditions as those from the dipped calf, all deposited eggs which weighed in the aggregate 2.1371 grams, 60 per cent of which hatched.

August 27, 32 engorged females were collected from the dipped calf, all but 8 of which died without laying eggs. These 8 deposited eggs weighing 0.0407 gram, none of which hatched.

August 28, 6 engorged females were collected, 4 of which deposited eggs weighing 0.1034 gram. None of these hatched. The other 2 died without depositing eggs.

August 29, three days after the first dipping, the last ticks to mature were collected. These were 9 in number. All but 1 of these died without ovipositing. This one laid about 75 eggs, none of which hatched.

No ticks with which the above may be compared were collected from undipped cattle between August 25 and September 7. The data previously given relative to 40 ticks collected on August 25 from an undipped calf should, however, be noted in comparison with the data relative to the ticks maturing on the dipped calf, and it may also be noted that 5 engorged females collected September 7 from undipped cattle deposited numerous eggs, 98 per cent of which hatched.

Experiment No. 9.

Beginning September 8, 1909, 3 calves, Nos. 725, 731, and 735, were artificially infested with ticks at the Bureau Experiment Station by applying larvæ every other day. October 22 ticks in all stages of development were present, but none of the 3 calves exhibited more than a moderate degree of infestation. A greater number of ticks in the various younger stages than in the later adult stage were present. The 3 calves were dipped October 22 in an arsenical dip freshly prepared from 7 pounds of arsenic trioxid, 8 pounds of anhydrous sodium carbonate, 0.7 gallon of pine tar, and 350 gallons of water. The dip contained an equivalent of 0.225 per cent arsenic trioxid.[1]

Calf No. 725 was immersed in the bath 2 minutes, calf No. 731 1 minute, and calf No. 735 30 seconds. After dipping the 3 calves were removed to a tick-free yard.

October 30, eight days after dipping, no skin injury was apparent. November 6 a dandruff-like scurf was noted on various parts of the body, but a similar condition was noted on the neck and dewlap of another calf which had never been dipped. In this experiment the skin injury may therefore be put down as so slight as to be scarcely if at all perceptible.

October 30, eight days after dipping, a very few live partially grown adults and a very few nymphs apparently alive were found on calf No. 725 (dipped 2 minutes); a few live, partially grown adults and a few nymphs apparently alive on No. 731 (dipped 1 minute); and on No. 735 (dipped 30 seconds) it was noted that partially grown females were present which were abnormally swollen from arsenical poisoning. No ticks matured on any of the three animals subsequent to October 26, four days after dipping. November 6, two weeks after dipping, the three calves when finally examined were found to be entirely free from ticks.

Twenty engorged females were removed from No. 725, October 22, immediately after dipping, 3 of which died without depositing eggs. The other 17 deposited eggs amounting in weight to 0.3273 gram, none of which hatched. From No. 731, immediately after dipping, October 22, 6 engorged females were removed, 2 of which survived to deposit eggs, which amounted in weight to 0.0262 gram. None of these hatched. From No. 735, October 22, immediately after dipping, 14 females were removed, all but 1 of which were fully engorged.

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[1] Analysis made in Biochemic Division.

Eleven of these survived to deposit eggs, whose weight amounted to 0.1933 gram. None of these hatched. In comparison it may be noted that 6 engorged females, removed from an undipped calf October 22 and kept under the same conditions as those from the dipped cattle, all deposited eggs which aggregated 0.2599 gram in weight and that 25 per cent of these hatched.

October 23, 15 engorged ticks were collected from calves Nos. 731 and 735. Twelve of these deposited eggs weighing 0.335 gram, none of which hatched. The other 3 died without ovipositing. Ten engorged females were collected from No. 725 on October 23, 4 of which survived to deposit eggs, the other 6 dying without ovipositing. The eggs which were laid aggregated 0.0515 gram in weight, and none of them hatched. Twelve engorged females collected from an undipped calf October 23 and kept under the same conditions as those from the dipped cattle all deposited eggs, which aggregated 0.4422 gram in weight. Ten per cent of these hatched.

October 24, 3 engorged females were collected from No. 725. All of these deposited eggs which amounted in weight to 0.0574 gram, none of them hatching. From No. 731 on October 24 were collected 1 fully engorged and 3 nearly engorged females. Two of these survived to deposit eggs which amounted in weight to 0.0335 gram. None of the eggs hatched. Twenty-one fully engorged and 8 nearly engorged female ticks were collected from No. 735 on October 24. Seventeen of these survived to lay eggs, the other 12 dying without ovipositing. The eggs laid amounted in weight to 0.2458 gram, and none of them hatched.

In comparison with the foregoing it may be noted that 13 females collected from an undipped calf on October 24 and kept under the same conditions as those from the dipped cattle all deposited eggs which amounted in weight to 1.0794 grams. One per cent of these hatched.

October 25, 4 engorged females were collected from No. 725, 1 of which survived to lay eggs, which weighed 0.0255 gram. None of these hatched. One small engorged female was collected from No. 731 on October 25. This tick died after depositing a very few eggs, none of which hatched. Eight fully engorged and 3 nearly engorged females were collected from No. 735 on October 25. Three of these ticks survived to lay eggs, which amounted in weight to 0.0372 gram. None of the eggs hatched. It may be noted in comparison with the foregoing that of 18 engorged females collected October 25 from an undipped calf and kept under the same conditions as those from the dipped cattle, 17 deposited eggs which amounted in weight to 0.5333 gram. Two per cent of these hatched.

October 26, 1 engorged female was collected from No. 731. This tick deposited eggs weighing 0.0397 gram, none of which hatched.

On the same date 4 females nearly engorged were collected from No. 735, all of which died without depositing eggs. Of 7 engorged females collected from an undipped calf October 26 and kept under the same conditions as those from the dipped cattle, all deposited eggs. These eggs amounted in weight to 0.3705 gram and 1 per cent of them hatched.

No ticks matured on calf No. 725 subsequent to October 25, three days after dipping, and none matured on Nos. 731 and 735 subsequent to October 26, four days after dipping.

Owing to the low relative humidity to which the eggs of the ticks were subjected in this experiment, and the consequent small percentage of eggs hatching in the case of the ticks from undipped cattle used for comparison, the failure of eggs deposited by ticks from the dipped cattle to hatch is less striking than in the other experiments.

Experiment No. 10.

November 10, 1909, eleven 3-year-old steers and one 4-year-old steer were dipped at Benjamin, Tex., in an arsenic, sal soda, and pine-tar dip containing an equivalent of 0.22 per cent arsenic trioxid.[1] The dip was prepared from 70 pounds of commercial arsenic (99.2 per cent arsenic trioxid [1]), 180 pounds of sal soda, 7 gallons of pine tar, and about 3,500 gallons of water. The vat used measured 35 feet 8 inches in length at the surface of the dip. The cattle in entering slipped down a slide board and, plunging into the bath, were totally immersed for a moment, after which they swam through the vat to the other end, where they left the bath by walking up an incline, which led to the draining pen. Each animal was in the bath from 10 to 12 seconds. The cattle were ordinary grass-fed steers in rather poor flesh, but strong and healthy. At the time the experiment was begun they all showed a moderate infestation with ticks in all stages of development.

The cattle were dipped on the afternoon of November 10. They remained in the stockyards overnight, and the following morning were driven about 5 miles to a small pasture, said to be badly infested with ticks, where they remained until the morning of November 17.

November 14, four days after dipping, each of the 12 cattle was examined. For this purpose they were placed one by one in a chute at the ranch where the cattle were pastured during the interval between dippings. The unusual gentleness of the cattle greatly facilitated this and the other examinations and handling to which they were subjected during the experiment. On animals Nos. 1, 4, and 6 a few live, fully engorged, partially engorged, and newly molted adult female ticks were found. All except the fully engorged ticks showed distinct evidence of the injurious effects of the dip; that is, they were unnaturally swollen and in some instances abnormal in color. On No. 12 slight exfoliation of the skin was evident at the root of the tail and on the escutcheon. One live engorged female and a few live ticks in stages just prior to and just after the second molt were found. Nos. 2 and 8 showed slight exfoliation of the skin, and harbored live ticks in stages just prior to and after the second molt. On Nos. 3 and 7 live, newly molted adult ticks were found, together with a few partially engorged females which were abnormally swollen and in a dying condition. No. 10 had a few live ticks partially engorged, and showed a slight exfoliation and tenderness of the skin on the escutcheon where the ticks had been numerous. The skin on the dewlap was slightly thickened and sensitive. On No. 5 there were a few live, newly molted adult ticks and the skin of the animal was very slightly affected. On No. 9 there was 1 fully engorged live tick, a number partially engorged, evidently poisoned by the dip, and a few live young adults. The skin of this animal showed a very slight exfoliation. On No. 11 there were a few live ticks, some of them young adults and some nearly engorged; all more or less affected by the dip. The skin showed scarcely any evidence of having been affected by the dip.

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[1] Analysis made in Biochemic Division.

November 17, one week after the first dipping, the cattle were driven back to the stockyards at Benjamin, where they were again examined. For this purpose the cattle were placed in the chute leading to the dipping vat. The cattle that exhibited signs of skin injury (i. e., slight irritation and exfoliation) November 14 showed similar signs at this examination. The animals presented the appearance of having gained in weight since dipping. No fully engorged females were found alive on these cattle November 17. On No. 1, some half-grown adult ticks were found to be alive, and there were some nymphs apparently alive. On No. 3 the only live ticks found were a few partially grown adults badly affected by arsenical poisoning. On No. 4 there were a few partially grown females alive but affected by the dip, and a few nymphs apparently alive. On No. 5, 1 recently molted female, and 1 partially grown female, both affected by the dip, were found alive, and there were present also some nymphs possibly alive. On No. 6, 1 newly molted male was found alive, and 1 nymph apparently alive. On No. 7 a small partially grown live female and a nymph apparently alive were found. One newly molted female affected by the dip was all that was found alive on No. 8. On No. 9 some newly molted adults were found alive and a very few nymphs apparently alive. No. 10 had a few partially grown female ticks, which were badly affected by the dip. On No. 11 only 1 tick was found alive, a female two-thirds grown, badly affected by the dip. No ticks were found on No. 12.

November 17, between 10 and 3 o'clock, the cattle were redipped in the dip remaining in the vat from the first dipping. During the dipping one of the animals became lodged in the vat in consequence of which he and 5 others remained in the bath nearly 1 minute. The remaining 6 were in the vat from 10 to 12 seconds each.

At 6 o'clock November 17 the 12 cattle were loaded into a stock car, partitioned in such a manner that they were confined to a little more than one-half the interior space of the car. This car was one which had been disinfected at Kansas City October 21 under supervision of a bureau inspector. It was further disinfected, before loading the cattle, by cleaning out all litter, sand, and dirt, and spraying with an arsenical solution of twice the strength of that used in dipping. At 8.20 p. m. the car of cattle left Benjamin in a local freight train, which arrived at Hamlin, Tex., about 55 miles distant, at 9.30 a. m. November 18. The cattle remained in the car at Hamlin and were brought back to Benjamin by a train which left Hamlin in the afternoon of November 18, and arrived in Benjamin about 1.30 a. m. November 19. The total period the cattle spent on the car was therefore about 31 hours. They were supplied with hay during this time, but not watered. At Benjamin they were unloaded into a pen at the railroad stockyards which had been thoroughly cleaned and disinfected by scraping off the surface earth with a team and scraper, scraping away also the surface of the earth from a strip about 3 feet wide all around the outside of the fence, and by spraying all the woodwork inside and out with the double-strength arsenical solution as used in the disinfection of the car; finally the ground along the fence inside and outside was soaked with the double-strength arsenical solution. When seen on the morning of November 19 the cattle appeared to be in good condition. Beginning on this date they were fed Johnson-grass hay and a cottonseed product from a local mill.

On November 22, five days after the second dipping, the cattle were examined individually, each animal being tied for examination against the fence by means of ropes attached to the horns and one hind foot. Each animal showed evidence of slight epithelial desquamation—in some instances very slight—exhibited in the form of a dandruff in the hair on the neck and at the root of the tail. This was the only skin injury evident. No live ticks were found on any of the animals except No. 8. In the case of this animal there was a partially grown female on the escutcheon abnormally swollen from arsenical poisoning, and a nymph near the root of the tail which was doubtfully alive.

November 24 these two ticks were still present on No. 8. The nymph appeared slightly shriveled. November 25 the tick was gone from the escutcheon and the nymph was still present but was dried and shriveled and certainly dead.

December 1, two weeks after the second dipping and three weeks after the first dipping, the cattle were again thoroughly examined as on November 22. More or less dandruff-like scurf from the skin was still present in the hair. The odor of pine tar, which was rather marked at previous examinations, had nearly disappeared. Many of the warbles with which all of the animals were more or less infested were examined and most of them proved to be alive. It is therefore evident that the arsenical dip has little effect on these parasites. No live ticks were found on any of the animals except one female near the root of the tail on No. 12. This tick was about one-sixth grown and was badly swollen from arsenical poisoning. Evidently this tick was one which had been overlooked at previous examinations. It no doubt passed through the first dipping and probably through the second as a nymph. During the examination it became detached, which prevented the possibility of determining its ultimate fate if it had remained on the animal. It was, however, so loosely attached that it could not have retained its hold much longer, and even if it had it was so badly affected by the dip that it is safe to say, in view of the history of ticks in a similar condition in other experiments, that it had no chance of ever reaching fertile maturity.

With reference to the weather conditions during the Benjamin experiments it may be noted (assuming that the records of the Weather Bureau station at Abilene, 80 miles distant, are applicable) that the only frost recorded was a killing frost on November 17, the day of the second dipping, and that this frost was the first of the season. The minimum temperature was 32° F., and this was recorded on November 17. The maximum temperature during the month of November was 84° F., recorded on the 5th, five days before the first dipping. The average daily maximum temperature during November was 71.6°, and the average daily minimum 50.1° F. Beginning November 10 the weather was clear on 5 days, cloudy on 5 days, and partly cloudy on 11 days. The average daily cloudiness for the month was 4.9 (Weather Bureau scale). On November 13, three days after the first dipping, 0.56 inch of rain fell between 11.10 a. m. and 2.40 p. m. On November 15 during the night 0.04 inch of rain fell. There was no further precipitation until November 28, when it began raining at 10.40 a. m., continuing until some time during the night, beginning again at 2.50 p. m., November 29, and ceasing at 9.40 p. m., the rainfall being 0.93 inch.

On the whole the weather was favorable to the experiment. No previous frost and an average temperature of 60° F. during the period between the two dippings when the cattle were on a pasture said to be tick-infested were circumstances favoring reinfection subsequent to the first dipping. The occurrence of rain three and five days after the first dipping, if it had any influence on the results of the dipping, would have tended to diminish the effectiveness of the treatment by washing off some of the arsenic which it may be assumed was left on the bodies of the cattle after dipping.

The cattle were released and the Benjamin experiment was closed after the examination December 1.

Experiment No. 11.

September 23, 1910, 16 engorged female ticks collected September 20, 1910, from infested cattle at the Bureau Experiment Station, were immersed two minutes in an arsenical dip taken from the vat at the station, were dried on filter paper, then placed in a Petri dish and kept under observation in the laboratory. The dip was prepared June 23 from 7 pounds arsenic trioxid, 6½ pounds sodium carbonate (anhydrous), 0.7 gallon of pine tar, and 350 gallons of water, and remained in the vat all summer, cattle being dipped in it from time to time. Samples taken June 23 and July 14 showed an equivalent, respectively, of 0.217 per cent and 0.218 per cent arsenic trioxid in solution.[1] A sample taken September 15 showed in solution sodium arsenite equivalent to about 0.04 per cent arsenic trioxid, and total arsenic in solution equivalent to 0.217 per cent arsenic trioxid.[1] Therefore, in the dip when used in this experiment, although the total arsenic in solution was the same as when the dip was made, considerable oxidation[2] of the sodium arsenite had taken place.

A second lot of 16 engorged ticks collected September 20 from station cattle were dipped two minutes, September 23, in a freshly made arsenical dip (10 grams arsenic trioxid, 25 grams sodium carbonate (crystallized), 8 c. c. pine tar, and sufficient water to make 4,150 c. c.), which it may be assumed contained sodium arsenite equivalent to about 0.24 per cent arsenic trioxid.

Another lot of 16 engorged ticks collected September 20 were kept without dipping under conditions similar to the two lots which were dipped.

Two of the ticks in the lot dipped in the oxidized dip deposited a few eggs, none of which hatched. The other 14 died without ovipositing. One of the ticks dipped in the fresh dip deposited about a dozen eggs, none of which hatched. The others died without ovipositing. All of the 16 ticks which were not dipped deposited eggs, and of these 40 per cent hatched.

This experiment was repeated, using a second series of 2 lots of engorged ticks, 15 in each lot, collected September 22. One of these lots was dipped September 23 in the oxidized dip and the other in the freshly made dip. Nine of the ticks dipped in the oxidized dip deposited a few eggs, none of which hatched, the other 6 dying without ovipositing. All of the ticks dipped in the fresh dip died without ovipositing.

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[1] Analysis made in Biochemic Division.

[2] For a discussion of the oxidation of arsenical dips see a paper by Aubrey V. Fuller, of the Biochemic Division, entitled "The Spontaneous Oxidation of Arsenical Dipping Fluids," published as Bureau of Animal Industry Circular 182.

September 26, 66 engorged ticks were collected from undipped cattle, and on September 28 two lots of 22 each were dipped 2 minutes in the same dips that were used before. A third lot of 22 was kept under observation undipped. Three of the ticks dipped in the oxidized dip deposited a few eggs, none of which hatched, the remaining 19 dying without ovipositing. All of the 22 ticks dipped in the fresh dip died without ovipositing. Of the 22 undipped ticks, all but one deposited eggs, and 25 per cent of the eggs hatched.

In the case of a fourth series of ticks, 2 lots of 21 each were collected October 3. October 4, 1 lot was dipped in the arsenical dip which was freshly made September 23. The other lot was kept under observation undipped. Of the former lot, 3 deposited a few eggs, none of which hatched, the remaining 19 ticks dying without ovipositing. All of the ticks of the second lot, except one, deposited eggs, and 75 per cent of the eggs hatched.

The rather low percentage of hatching among the eggs deposited by the undipped ticks was due to the low relative humidity of the air of the room, where the ticks and eggs were kept during the experiments, and it is possible that some of the eggs deposited by the dipped ticks might have hatched had the conditions as to moisture been more favorable.

Experiment No. 12.

During the summer and fall for several weeks prior to October 10, 1910, 7 young cattle at the Bureau Experiment Station were artificially infested with ticks by applying larvæ every few days. On the date named 6 of them were sprayed with arsenical solutions by means of a hand spray pump. Three different solutions were used, and 2 cattle were sprayed with each solution. The seventh animal was reserved untreated as a control. All of the cattle were kept after dipping in the pen which they had occupied prior to the treatment, and four days after spraying larval ticks were applied to each animal.

Lot A.—The two cattle in this lot were sprayed with the oxidized dip referred to in Experiment No. 11. A sample taken from the vat October 20 showed that oxidation of the arsenic had continued since the taking of the previous sample, September 15, the amount of sodium arsenite present having been reduced to the equivalent of about 0.02 per cent arsenic trioxid,[1] though the total arsenic in solution was the same as before.

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[1] Analysis made in Biochemic Division.

At the time of spraying one of the cattle was slightly infested, the other moderately infested with ticks in all stages of development. Three days later the cattle were examined. One of them showed a slight exfoliation of the skin on the dewlap; on the other the skin was unaffected. On one animal a few live nymphs and adults, some of the latter engorged females, were found. On the other there were live ticks in various stages, mostly nymphs, but some engorged females apparently in good condition were noted.

Ten days after the spraying one of the cattle showed exfoliation of the epidermis on the crest of the neck and withers, and on the dewlap, very slight in the latter location. Very slight exfoliation confined almost entirely to the dewlap was noted in the case of the other animal. On one of the cattle a live larva nearly ready to molt was found, also several live males, and females which had evidently molted a few days before the examination. On the other there were 5 apparently healthy engorged females with live males, and a dozen or more newly molted females, all more or less affected by the dip.

October 20, 10 days after the first spraying, the cattle were again sprayed with some of the same dip as before.

Four days later the cattle were examined. Slight exfoliation of the epidermis was found as before. On one a recently molted female and a male were found alive, on the other an engorged female and a recently molted female and 2 males.

Seven days after the second spraying the skin injury was still very slight. A half-grown adult female and a male on one animal and a two-thirds grown adult female on the other animal were the only live ticks found.

Eleven days after the second spraying one of the cattle showed a hard granular exfoliation of the skin on the withers; the other showed no signs of skin injury. No ticks were found on one. On the other there was an engorged female, 2 adult females one-fourth grown, and 3 males.

Fourteen days after the second spraying the exfoliation of the epidermis on the withers was still noticeable in the case of one of the cattle. No ticks were found on this animal. On the other a partially engorged female and a nymph were found to be alive.

Twenty-one days after the second spraying the last examination was made. There were no longer any signs of skin injury. One of the animals was free from ticks; the other had several partially grown adult females on the belly, some of them newly molted.

So far as possible all of the engorged females were collected as they matured on the treated animals, beginning immediately after the first spraying. These were brought to the laboratory and kept under observation in Petri dishes. For comparison engorged and partially engorged ticks were collected from time to time from the untreated animal which served as a control and these were kept under the same conditions as those from the sprayed cattle.

Immediately after the first spraying 11 engorged ticks were collected from one of the sprayed cattle and 3 from the other. Three of the former died without ovipositing, and 8 deposited eggs, none of which, however, hatched. All 3 of the ticks from the other animal deposited eggs, and 5 per cent hatched.

For comparison it may be noted that all of 29 ticks collected on the same date from the untreated animal deposited eggs, and that 40 per cent of them hatched.

One day after spraying 29 ticks were collected from one of the treated animals, 25 of which deposited eggs. None of the eggs hatched. Forty-five ticks collected the same day from the untreated animal all deposited eggs, 75 per cent of which hatched.

Two days after spraying 8 ticks were collected from one of the treated animals, and 7 of these deposited eggs, but none hatched. All of 14 ticks collected the same day from the untreated animal deposited eggs, of which 4 per cent hatched.

Three days after spraying 8 ticks were collected from one of the treated animals. All deposited eggs, but none of them hatched. All of 8 ticks collected from the unsprayed animal on the same date deposited eggs, but less than 1 per cent hatched.

Four days after spraying 1 tick was collected from one of the sprayed cattle. This tick deposited eggs, but none hatched. On the same date 2 ticks were collected from the untreated animal. Both deposited eggs, but none hatched.

No ticks were collected from the treated cattle for observation later than four days after the first spraying.

Lot B.—The two cattle of this lot were sprayed with an arsenical dip freshly made from 91 grams of arsenic trioxid, 84 grams of sodium carbonate (anhydrous), 75 c. c. of pine tar, and 10 gallons of water. Analysis [1] showed an equivalent of 0.234 per cent arsenic trioxid in solution. One of the animals when sprayed was rather heavily infested, the other lightly infested with ticks in all stages of development.

Three days after spraying no injury to the skin was noted. On one of the animals were noted numerous live ticks, nymphs and adults, some of the latter engorged, others partially grown and abnormally swollen from the effects of the dip. On the other there were a few live nymphs and some engorged ticks.

Ten days after spraying one of the cattle showed a very slight exfoliation of the epidermis on the crest and side of neck, and an exfoliation at the base of the tail and thickening of the skin in the anal region. On the other animal there was a slight exfoliation at the base of the tail and in front of the right shoulder. No live ticks were found on one. On the other several nymphs were noted on the escutcheon as possibly alive, and a cluster of live ticks of various stages from young nymphs to engorged females was found on the inner side of the flank.

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[1] Made in Biochemic Division.

Ten days after the first spraying the two cattle in this experiment were sprayed again with an arsenical dip freshly prepared from 7 pounds arsenic trioxid, 6½ pounds sodium carbonate (anhydrous), 0.7 gallon pine tar, and 350 gallons of water, containing an equivalent of 0.22 per cent of arsenic trioxid.[1]

Four days after the second spraying an exfoliation of the epidermis on the brisket, right shoulder, and at the root of the tail was noted on one animal, and an exfoliation at the root of the tail and in the sacral region was observed on the other animal. No ticks were found on one. A live nymph and a recently molted female were found on the other in the right inguinal region.

Seven days after the second spraying the exfoliation of the skin was still slightly noticeable. No ticks were found on one animal. On the other the same 2 ticks noted at the previous examination were found, namely, a nymph and a female.

Eleven days after the second spraying one of the animals showed no signs of epidermal exfoliation. Slight exfoliation was still evident in the case of the other. On the animal which showed tick infestation at the two preceding examinations a young female, a male, and a nymph were found alive in the right inguinal region. A female one-sixth grown and a male were found on the other animal, whose presence was evidently overlooked at the preceding examination.

Fourteen days after the second spraying the evidences of skin injury were still slight. No ticks were found on one of the animals, the female one-sixth grown and the male noted at the preceding examination having disappeared. A partially grown female, a male, and a newly molted female were found in the right inguinal region of the other animal, evidently the same ticks noted at the preceding examination.

Twenty-one days after the second spraying when the final examination was made no ticks were found on either animal. One of the animals still presented a slight epidermal exfoliation at the root of the tail, sides of hocks, and on the escutcheon.

The same procedure with reference to the removal of ticks for further observation was followed as in the case of Lot A.

Thirty-seven ticks were removed from one animal and 2 ticks from the other immediately after the first spraying. Of the former, 6 deposited a very few eggs and none of these hatched, the other 31 dying without depositing eggs. Both of the ticks from the other animal deposited eggs, none of which hatched. For comparison it may be noted that 29 ticks collected at the same time from the untreated animal (already referred to under Lot A) all deposited eggs, of which 40 per cent hatched.

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[1] Analysis made in Biochemic Division.

One day after spraying 31 ticks were collected from the sprayed cattle, 18 of which deposited eggs. None of the eggs hatched. All of the 45 ticks collected on the same day from the untreated animal (as noted under Lot A) deposited eggs, of which 75 per cent hatched.

Two days after spraying 12 ticks were collected from the sprayed cattle, 6 of which oviposited. None of the eggs hatched. The 14 ticks collected from the untreated animal on the same day all deposited eggs, of which 4 per cent hatched.

Three days after spraying 4 ticks were collected from the sprayed cattle. Two of these deposited eggs, but none hatched. All of the ticks, 8 in number, collected from the untreated animal on the same day, deposited eggs. Of these less than 1 per cent hatched, however.

No ticks were collected from the cattle in this lot after the third day subsequent to the first spraying.

The same remarks concerning the effects of the low relative humidity on the eggs of the ticks apply in the case of this lot as in the case of Lot A.

Lot C.—The two cattle of this lot were sprayed with a special arsenical dip devised by Mr. Chapin of the Biochemic Division, bearing the laboratory designation of Tick Dip B. It contained potassium arsenite, pine tar, and some soap. The amount of arsenic in solution in a sample of the dip as diluted for use was equivalent to 0.222 per cent arsenic trioxid.[1] Both of the cattle sprayed with this dip were rather heavily infested with ticks in all stages of development.

Three days after spraying a slight epidermal exfoliation on the dewlap and at the root of the tail was noted on one of the animals, and a slight exfoliation on the escutcheon where the ticks had been numerous was noted on the other animal. On one animal numerous live nymphs and adults, some engorged, were observed. Many of the adult ticks were abnormally swollen. On the other animal were observed partially grown adult ticks, alive, but mostly abnormally swollen and dark in color. Some nymphs apparently in good condition were also seen.

Ten days after spraying one of the cattle showed a slight epidermal exfoliation on the crest of the neck, on the shoulders, and on the brisket, and a slight scurf on the side of the neck. The skin of the dewlap was thickened and exfoliating. There was some exfoliation at the base of the tail, on the escutcheon, and inner side of thighs, with thickening of the skin. There was some exfoliation with slight soreness of the skin on the belly opposite the flank. The other animal showed similar skin conditions, but to a less degree. On the former there was a larva apparently alive located near the root of the tail. No live ticks were found on the other. Dead ticks were numerous on both animals.

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[1] Analysis made in Biochemic Division.

Ten days after the first spraying the cattle were sprayed again with Tick Dip B used at the same dilution as before. No analysis was made of the dip used at the second spraying. It is assumed, however, that the percentage of arsenic in the dip was the same as at the first spraying.

Four days after the second spraying the evidences of skin injury were less marked than at the preceding examination. No live ticks were found on either animal.

Seven days after the second spraying exfoliation and thickening of the skin were still noticeable. No live ticks were found on either animal.

Eleven days after the second spraying slight exfoliation of the skin in the anal region and on the escutcheon with considerable thickening in the latter location were noted on one animal. On the other the edge of the dewlap was dry and hard, and there was some exfoliation on the root of the tail. No ticks were found on either animal.

Fourteen days after the second spraying slight evidences of the effects of the dip on the skin were still present. No ticks were found on either animal.

Twenty-one days after the second spraying the evidences of skin injury were still noticeable. No ticks were found on either animal.

The following observations were made on ticks removed from the cattle after spraying and kept in the laboratory:

Immediately after the first spraying 59 ticks were removed from one of the cattle and 18 from the other. All died without depositing eggs. In comparison it may be noted that 29 ticks removed from the unsprayed animal on the same day all deposited eggs, of which 40 per cent hatched.

One day after spraying 15 ticks were collected from the sprayed cattle. Seven of the ticks deposited eggs, of which none hatched. The 45 ticks removed on the same day from the unsprayed animal all deposited eggs, of which 75 per cent hatched.

Two days after spraying 6 ticks were collected from one of the sprayed cattle. Three of these deposited eggs, none of which hatched. Fourteen ticks collected the same day from the unsprayed animal all deposited eggs, of which 4 per cent hatched.

No engorged ticks were collected from the sprayed cattle later than two days after spraying.

Notes on the untreated animal.—On the day the cattle in this experiment were sprayed the second time the untreated animal exhibited a slight epidermal exfoliation on various parts of the body. Ticks in all stages of development were numerous.

Four days after the second spraying of the rest of the cattle the untreated animal showed a slight scurfiness of the skin in various places. Ticks were still numerous, especially on the escutcheon.

Seven days after the second spraying of the rest of the cattle numerous ticks in all stages of development, most abundant on the escutcheon, were noted on the untreated animal.

Eleven days after the second spraying of the rest of the cattle the presence of nymphs and adult ticks, abundant on the escutcheon and lower part of dewlap, was noted on the untreated animal.

Fourteen days after the date of the second spraying a few nymphs and numerous adults were noted on the unsprayed animal.

Twenty-one days after the date of the second spraying numerous adult ticks in various stages of growth were present on the unsprayed animal. One nymph was found at this time.

ARSENIC, SODA, AND PINE-TAR DIP CONTAINING EMULSIFIED CRUDE PETROLEUM.

Experiment No. 13.

Fifty gallons of crude petroleum mixed with 12½ gallons of hot concentrated soap solution were added to the arsenic, soda, and pine-tar dip used in experiment No. 2. A fairly good emulsion was obtained. No analysis of this dip was made, but it may be estimated that it contained about 10 per cent of crude petroleum and an equivalent of somewhat less than 0.172 per cent arsenic trioxid. October 22, 4 cattle were sprayed with this mixture in the same machine as used in experiment No. 2. The machine did not work properly during the spraying of these animals. October 23, 57 cattle were sprayed. The machine worked well and these animals received a thorough spraying. On both dates the cattle were held in the machine at least 10 seconds each. Most of them were grossly infested with ticks in all stages of development.

Many of the cattle were rather severely injured by the treatment, the skin becoming thickened, cracked, chafed, and sore to the touch, with exfoliation, and the animals showed more or less stiffness and lameness as a result of the skin injury. The injurious effects of the treatment were still well marked 8 days after the treatment. The cattle in this experiment were more seriously injured than others of the same herd sprayed with a 25 per cent emulsion of crude petroleum, and were much more seriously injured than those in experiment No. 2 sprayed with the arsenical solution before the addition of the crude petroleum.

Cattle closely examined 7 and 8 days after spraying were free from ticks, and others seen 8 days after spraying during a ride through the herd were apparently free from ticks.

Thirty-eight engorged ticks were removed from some of the cattle 14 hours after spraying. Twenty-nine of these died without depositing eggs. The remaining 9 laid a few eggs, none of which hatched. Thirty-four engorged ticks were removed from the cattle 3 days after spraying. One of these laid a few eggs, none of which hatched; the other 33 died without depositing eggs. Fourteen ticks collected October 22 from untreated cattle and kept under the same conditions as those from the sprayed cattle deposited numerous eggs, most of which hatched. Another lot of 6 engorged ticks taken from untreated cattle on the same date deposited about 1,000 eggs, about 100 of which hatched. None of 10 nymphs collected 14 hours after spraying molted, and 9 nymphs collected 3 days after spraying all failed to molt. All but 4 out of 25 nymphs collected October 22 from untreated cattle and kept under the same conditions as those from the sprayed cattle afterwards molted.

ARSENIC AND ZINC SULPHATE DIP.

Experiment No. 14.

August 7, 1909, a tick-infested calf was dipped at the Bureau Experiment Station in a dip consisting of arsenic trioxid, zinc sulphate, and water, containing 0.476 arsenic trioxid in solution.[1]

In this dip the same ingredients were used and in the same proportion as those used in the so-called "arsenical dip of Trasbot" employed in France for dipping scabby sheep, omitting, however, the aloes which is included in Trasbot's dip, with the further difference also that only about half the arsenic used was brought into solution, although it was submitted to prolonged boiling.

The calf had been artificially infested and at the time of dipping ticks in all stages of development were present. The period of immersion in the bath was two minutes, and after dipping the calf was kept in a noninfested pen. The calf was seriously injured by the dip. The skin in places became much thickened and cracked, with much exfoliation and some loss of hair, and the animal fell off in flesh considerably. Recovery from the effects of the dipping required nearly a month. No ticks matured later than two days after dipping and all that matured after dipping died without depositing eggs. The calf was entirely free from live ticks six days after dipping.

Immediately after dipping, August 7, 49 engorged ticks were removed from the calf. All of these died without depositing eggs.

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[1] Analysis made in Biochemic Division.

For comparison it may be noted that 24 out of a lot of 25 small and only partially engorged ticks collected from an undipped animal on the same date and kept under the same conditions deposited eggs which weighed 0.3036 gram, 12 per cent of which afterwards hatched.

August 8, 5 engorged and 7 partially engorged females were collected from the calf, all of which died without depositing eggs. For comparison note that 1 fully engorged and 3 partially engorged females collected from an undipped calf on August 8 and kept under the same conditions as the ticks from the dipped calf all deposited eggs weighing 0.1365 gram, 75 per cent of which hatched.

August 9, after which date no ticks matured on the calf, 6 nearly replete females were collected, all of which died without depositing eggs. For comparison note that 1 female, nearly replete, collected from an undipped calf on the same date and kept under the same conditions as the ticks from the dipped calf deposited eggs weighing 0.0295 gram, 80 per cent of which hatched.

The dip used in this experiment had the effect of destroying not only the younger ticks but also affected the engorged and nearly engorged ticks so seriously that they died without depositing eggs.

Judging from the results of this experiment, the dip used, although it proved very efficacious as a tick killer, has no practical value as a cattle dip on account of its severe effects and the difficulty of dissolving the arsenic in preparing it.

Experiment No. 15.

August 8, 1909, 46 fully engorged female ticks were collected from an undipped calf at the Bureau Experiment Station. These were immersed for two minutes in some of the solution used in experiment No. 14, which contained 0.476 per cent arsenic trioxid. After dipping, the ticks were dried on filter paper, placed in a Petri dish, and kept under observation in the laboratory. Forty-four of these ticks died without depositing eggs. The other 2 deposited eggs amounting in aggregate weight to 0.0078 gram, none of which hatched. Out of 46 engorged ticks collected August 8 and kept under the same conditions as the ticks referred to above, except that they were not dipped, 45 deposited eggs whose aggregate weight amounted to 2.5975 grams, and 98 per cent of them hatched. Another lot of 4 females collected August 8 and kept under the same conditions deposited eggs weighing 0.1365 gram 75 per cent of which hatched.

ARSENIC-ALUM DIP.

Experiment No. 16.

August 10, 1909, a calf which had been artificially infested with ticks was dipped at the Bureau Experiment Station in a dip consisting of arsenic trioxid, alum, and water, containing 0.495 per cent arsenic trioxid in solution.[1] This dip is similar to a dip used more or less in Europe for the treatment of sheep scab.

At the time of dipping, ticks in all stages of development were present on the calf. The animal was immersed in the dip for two minutes. After dipping the calf was kept in a noninfested pen.

The skin of the calf was slightly injured by the dipping to the extent that in places some thickening with exfoliation occurred, which was still noticeable August 20, but had disappeared by September 9. The animal was entirely free from ticks within eight days after dipping. No ticks matured on the calf later than three days after dipping. All that matured either died without ovipositing or deposited only a few eggs, none of which hatched.

This dip was very efficacious and produced only slight skin injury. The difficulty of preparing it, however—that is, of dissolving the arsenic trioxid—renders it undesirable for practical use.

August 10, immediately after dipping, 43 engorged and nearly engorged female ticks were collected. All of these died without depositing eggs. Later in the same day 19 engorged females were collected, all but 4 of which died without depositing eggs. These 4 deposited eggs amounting to 0.013 gram in weight, none of which hatched. For comparison with the above it may be noted that 21 out of a lot of 22 females, none fully grown, collected August 10 from an undipped animal and kept under the same conditions as those from the dipped calf deposited eggs aggregating 0.4242 gram in weight, and that 50 per cent of these hatched.

August 11, 18 females (6 engorged and 12 partially engorged) were collected, 3 of which deposited eggs weighing 0.0495 gram, none of which hatched. The other 15 died without depositing eggs. In comparison note that 18 females (4 fully engorged and 14 nearly engorged) collected from undipped cattle August 11 and kept under the same conditions all deposited eggs weighing 0.2441 gram, 40 per cent of which hatched.

August 12, two days after dipping, 14 females (6 fully engorged and 8 nearly engorged) were collected, and 2 of these laid eggs weighing 0.0082 gram. The other 12 ticks died without ovipositing. None of the eggs hatched. In comparison note that 5 females (3 fully engorged and 2 partially engorged) collected from undipped cattle August 12 and kept under the same conditions all deposited eggs weighing 0.1555 gram, and that 60 per cent of these hatched.

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[1] Analysis made in Biochemic Division.

August 13 was the last day on which any ticks matured on the calf in this experiment. On this date 6 females (3 fully engorged and 3 partially engorged) were removed, 1 of which survived to deposit eggs weighing 0.0293 gram. None of these hatched. In comparison note that 17 engorged females collected from an undipped calf August 13 and kept under the same conditions as those from the dipped calf all deposited eggs weighing 0.8953 gram, and that 97 per cent of these hatched. It may also be noted that 1 engorged female removed from an undipped calf August 13, and kept under the same conditions as the ticks from the dipped calf, deposited eggs weighing 0.0426 gram, and that 40 per cent of these hatched.

Experiment No. 17.

Fifty-nine engorged female ticks, collected August 10, 1909, from cattle at the Bureau Experiment Station, were immersed two minutes on August 11 in some of the dip used in Experiment No. 16, which contained 0.495 per cent arsenic trioxid. After dipping, the ticks were dried on filter paper, placed in a Petri dish, and kept under observation in the laboratory. Fifty-seven of these ticks died without depositing eggs. The other two deposited eggs whose aggregate weight amounted to 0.0123 gram. None of these eggs hatched.

Fifty-eight in a lot of 59 undipped ticks, collected at the same time as those just referred to, deposited eggs whose aggregate weight equaled 2.773 grams, and 97 per cent of which hatched, having been kept under the same conditions as those from the dipped ticks.

SODIUM ARSENATE DIP.

Experiment No. 18.

November 10, 1910, 60 engorged ticks collected from an infested bull at the Bureau Experiment Station were divided into 3 lots of 20 each and kept in the laboratory in Petri dishes, all under similar conditions. Sufficient moisture to insure the hatching of normal eggs was provided by the presence of sand in the dishes, which was kept moist.

Lot No. 1 was dipped two minutes on November 10 in a neutral solution of sodium arsenate containing an equivalent of 0.22 per cent arsenic trioxid.[1]

Lot No. 2 was dipped two minutes on the same date in a slightly alkaline solution of sodium arsenate containing an equivalent of 0.22 per cent arsenic trioxid.[1]

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[1] Solution prepared in Biochemic Division.

Lot No. 3 was not dipped.

All but one of the first lot of ticks deposited eggs, of which 1 per cent hatched. All of the second lot deposited eggs, of which 2 per cent hatched. The third lot of ticks, which were not dipped, all deposited eggs, of which 99 per cent hatched.

SODIUM SULPHARSENITE DIP.

Experiment No. 19.

Twenty-two engorged ticks, collected October 19 and 20, 1910, from an infested bull at the Bureau Experiment Station, were dipped two minutes, October 21, in a slightly alkaline solution of sodium sulpharsenite containing an equivalent of 0.22 per cent arsenic trioxid.[1] After dipping, these ticks were placed in a Petri dish and kept under observation in the laboratory.

On the same date 22 engorged ticks collected at the same time and from the same animal as the preceding lot were dipped two minutes in an arsenic, soda, and pine-tar dip, made October 20, which contained an equivalent of 0.22 per cent arsenic trioxid.

A third lot of 22 engorged ticks also collected at the same time and from the same animal as the other two lots was kept under observation undipped. Except as to dipping, all three lots were handled in the same manner and kept under the same conditions.

Of the lot dipped in sodium sulpharsenite all but three deposited eggs. November 11 about half the eggs were normal, but none hatched. All of the ticks dipped in the arsenic, soda, and pine-tar dip died without ovipositing. All of the undipped ticks deposited eggs, practically all of which were normal on November 11. Less than 1 per cent of the eggs hatched.

The low relative humidity of the air of the laboratory was unfavorable to the hatching of the eggs in this experiment.

POTASSIUM ARSENITE DIP CONTAINING SOAP.

Experiment No. 20.

Twenty cattle heavily infested with ticks—some very heavily—were selected from a herd on the Rincon ranch, near Gregory, Tex., and these animals were dipped June 25, 1910. The dip used was a proprietary arsenical mixture. When diluted the dip contained an equivalent of 0.202 per cent arsenic trioxid[2] in the form of potassium arsenite. It also contained some soap in addition to other ingredients of minor importance. The vat used was about 93 feet in length at the surface of the dip. Each animal was in the bath from 30 to 60 seconds. After dipping, some of the cattle were kept in disinfected pens and some on infested pasture. Five to nine days after dipping an exfoliation of the epidermis appeared, rather marked in the case of 2 bulls, but generally slight in the case of the remaining animals, only 2 of which exhibited evidences of more than very mild skin injury. One of these showed a rather severe exfoliation on the escutcheon, thighs, dewlap, and other parts of the body, and the other showed a rather severe exfoliation of the skin on the dewlap, the exfoliation on the posterior parts of the body being slight. The exfoliation in the case of the 2 bulls which were dipped but once was described as rather severe, causing a loss of hair on the inner side of the thighs. In no instance, however, was the exfoliation preceded by noticeable inflammation.

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[1] Solution prepared in Biochemic Division.

[2] Analysis made in Biochemic Division.

July 5, 10 days after the first dipping, all but 3 of the cattle were dipped a second time in the same vat and in the same dip, to which more water had been added. At the second dipping the dip contained an equivalent of 0.197 per cent arsenic trioxid.[1] Following the second dipping the cattle which had been on infested pasture between dippings were returned to the infested pasture, except 2 which were placed in a disinfected pen. Those which had been in disinfected pens between dippings were returned to the same pens.

The cattle were examined individually on June 25, before dipping, and every few days thereafter, the final examination being made on July 18, two weeks after the second dipping.

Eight to 13 days after the second dipping a fresh exfoliation of the epidermis became evident on some of the animals, but it was, as a rule, much less marked than the exfoliation following the first dipping.

Within four days after the first dipping most of the ticks were dead. All but 7 of the cattle, so far as could be determined from careful examination, were free from live ticks 9 days after the first dipping. At that time the ticks found alive were 2 recently molted females, 8 males (6 of them newly molted), and 6 nymphs. The following day an additional male was found, making 17 the total recorded number of live ticks present on the cattle just prior to the second dipping.

None of the 3 cattle which were dipped but once and subsequently kept in a disinfected pen showed any infestation after July 2, 7 days after dipping. A very plump female one-fourth of an inch long was found on one of the twice-dipped cattle 2 days after the second dipping. This tick was found dead 2 days later. Four days after the second dipping a very plump female one-third of an inch long was found on another animal. This tick was removed and placed in a pill box. It died without depositing eggs. At the final examination a female tick which had molted several days before was found. Except for larvæ which were found at the final examination on the cattle which occupied infested pasture, these 3 ticks were all that were found upon the cattle subsequent to the second dipping. Most of the larvæ found at the final examination were not more than 1 to 2 days old (reckoning from date of attachment). Only one was found which was older. This one had possibly been attached for as long as 4 days.

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[1] Analysis made in Biochemic Division.

From time to time after the first dipping ticks were removed from the dipped cattle and placed in boxes for further observation, and at the same time ticks were removed from undipped cattle and kept under the same conditions for comparison with those from the dipped cattle.

All of the engorged females (10) removed from the cattle immediately after dipping died without depositing eggs. Four out of 20 partly engorged females deposited eggs, none of which hatched. Eleven engorged and 25 partly engorged females removed from undipped cattle on the same date deposited eggs, about 50 per cent of which hatched.

Two days after dipping, 48 engorged and 26 partially engorged females were removed from the dipped cattle. About 20 of the former and 5 of the latter deposited eggs. None of the eggs laid by the latter hatched and about 1 per cent of those laid by the former hatched. On the same date 14 female ticks not more than half grown were removed from undipped cattle. About 3 per cent of the eggs deposited by these ticks hatched.

Three days after dipping, 22 fully engorged and 18 partially engorged ticks were removed from the dipped cattle. About 10 of the former oviposited. Some of the latter also deposited eggs, none of which hatched. Less than 1 per cent of the eggs deposited by the engorged females hatched. On the same date 1 engorged and 13 partially engorged females were removed from undipped cattle. Most of these deposited eggs, and about 10 per cent of the eggs hatched.

Four days after dipping, 3 partially engorged females were removed from the dipped cattle. All of these died without depositing eggs. On the same date 3 females one-fourth to one-half grown were removed from undipped cattle. These deposited eggs, 60 per cent of which hatched.

Five days after dipping, 1 engorged female was removed from one of the dipped cattle. This tick died without ovipositing. On the same date 1 engorged and 2 two-thirds grown females were removed from an undipped bull. All of these deposited eggs, 95 per cent of which hatched.

Six days after dipping, a female tick not more than one-half grown was removed from one of the dipped cattle. This tick died without depositing eggs.

Fourteen days after the first dipping and 4 days after the second dipping, a very plump female one-third of an inch long was removed from one of the dipped cattle. This tick died without depositing eggs.

Immediately after dipping, 12 nymphs were removed from the dipped cattle. None of these molted. At the same time 20 nymphs were removed from undipped cattle. All but one of these molted.

Two days after dipping, 17 nymphs were removed from the dipped cattle. None of these molted. On the same date 2 nymphs were removed from undipped cattle, and both molted.

Three days after dipping, 41 nymphs were removed from the dipped cattle. None of these molted.

Four days after dipping, 54 nymphs were removed from the dipped cattle. None of these molted. On the same date 42 nymphs were removed from undipped cattle, 27 of which molted.

Five days after dipping, 46 nymphs were removed from the dipped cattle. None of these molted. On the same date 12 nymphs were removed from an undipped bull, and 10 of them molted.

Six days after dipping, 1 nymph was removed from one of the dipped cattle. This nymph failed to molt.

Experiment No. 21.

This experiment was conducted under the supervision of Dr. Dick E. Warner, veterinary inspector, assisted by Mr. Charles H. Gibson, agent in tick eradication, both of the Bureau of Animal Industry. The following account is summarized from Dr. Warner's report:

October 26, 1910, 20 head of tick-infested cattle were dipped on the Woodley ranch near Tulsa, Okla. These cattle were all grossly infested with ticks in all stages of development, including some larvæ. The infestation was most pronounced along the inside of the thighs, on the escutcheon, neck, dewlap, and along the anterior border of the scapula. The animals were infested to a less degree on all other parts of the body. In several instances the infestation reached the degree known as "shingled," and in some instances ticks were noted within the ears. All the cattle carried a heavy winter coat of hair. All were in good health at the time of dipping with the exception of 2, which presented the appearance of having recently suffered from an attack of fever. During the experiment these 2 animals constantly improved in condition.

The dip used was a proprietary arsenical dip of the same brand as that used in experiment No. 20. When diluted for use it contained an equivalent of 0.224 per cent arsenic trioxid.[1]

The vat in which the cattle were dipped was 31 feet in length at the surface of the dip. Each animal was held in the bath from 13 to 15 seconds. After dipping, 4 of the cattle were placed in a tick-free pen, and the remaining 16 in a small infested pasture. In view of the cool weather prevailing, it is probable that the latter were exposed to but slight chances of reinfestation. A heavy frost occurred every night but one during the experiment, and at times ice formed during the night to a thickness of one-third of an inch. There was no rain during the experiment.

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[1] Analysis made in Biochemic Division.

After dipping, the cattle were examined at intervals of a few days. A slight exfoliation of the epidermis was noted, beginning 4 days after dipping. At no time did this exfoliation become extensive, nor was it accompanied by inflammation. No injury to the skin or hair was noted.

Most of the ticks had disappeared by the fourth day after dipping. No live larval ticks were found subsequent to dipping. Eight days after dipping 2 live males were found on 1 animal. On 8 cattle 14 nymphs apparently alive were found 8 days after dipping. On 18 of the cattle 99 live females, from newly molted to one-half grown, were found 8 days after dipping. Thirty-one female ticks over half grown were found on 6 of the cattle 8 days after dipping. Thirteen of these were stated to be mature. Two cattle were free from ticks 8 days after dipping. One of these had been kept in the disinfected pen, the other in the infested pasture.

November 4, 18 of the cattle were dipped again. The other 2 were not dipped a second time, but were kept under observation for 23 days after dipping and were still infested with ticks at the end of this time. Both of these animals occupied the infested pasture after dipping. No live nymphs were noted on one of these cattle subsequent to October 30. One nymph apparently alive was noted on the other 8 days after dipping, but none was found subsequently. Twenty-three days after dipping the only ticks found on the cattle which were dipped but once were 3 females on one and 1 female on the other.

At the second dipping the dip which was left in the vat since the first dipping was used. A sample taken at the time of the second dipping showed the presence of an equivalent of 0.233 per cent arsenic trioxid.[1] Each animal dipped was held in the bath 13 to 15 seconds, except one, which was held but 9 seconds. Following the second dipping 12 of the cattle dipped were placed in the infested pasture and 6 in the disinfected pen. Four of these 6 had occupied the pen between the 2 dippings; the other 2 had been in the infested pasture.

The effects of the second dipping on the skin were described as extremely mild, consisting of slight exfoliation, noted in the case of only 2 animals. Twelve days after the second dipping the exfoliation due to the first dipping continued in a mild form, unaccompanied by inflammation, and without noticeable injury to the hair or skin.

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[1] Analysis made in Biochemic Division.

A nymph apparently alive was found on each of 2 cattle out of a total of 7 examined two days after the second dipping. No live nymphs were afterwards found on any of the twice-dipped cattle. No live males were found subsequent to the second dipping. On 5 of the 7 cattle examined, 14 female ticks were found, ranging in development from newly molted to two-thirds grown. The other 2 cattle were free from ticks and none was afterwards found on them. Four days after the second dipping 11 cattle were examined and 2 found to be infested. Two female ticks one-sixth grown and 1 female tick two-thirds grown were found on 1 of the 2 infested cattle, and 1 female tick about one-half grown on the other, a total of 4 ticks. The other 9 cattle were free from ticks and none was found on them subsequently. Six days after the second dipping 8 cattle were examined and 1 of them was found to be infested with a female tick one-half grown. This animal was 1 of the 2 found infested 4 days after the second dipping. Eight days after the second dipping 10 cattle were examined, including the 1 found infested 6 days after dipping. No live ticks were found. Ten days after the second dipping 8 cattle were examined and on 1 of them was found a female tick over one-half grown. This was the last tick found subsequent to the second dipping. The animal on which it was found was 1 of those examined 6 days after dipping and at that time was apparently free from ticks. The tick showed evidences of the injurious effects of the dip. Two days later or 12 days after the second dipping this tick had disappeared. Fourteen days after the second dipping all of the twice-dipped cattle were free from ticks.

From time to time after the first dipping ticks were removed from the dipped cattle and placed in boxes for further observation. Ticks were also removed from undipped cattle and kept under similar conditions for comparison with those from the dipped cattle.

Engorged and partially engorged females.—One hour after the first dipping 100 engorged females were removed from the dipped cattle. All of these died without depositing eggs. Another lot of 100 engorged females removed at the same time from undipped cattle all deposited eggs.

Two days after dipping 60 engorged or nearly engorged female ticks and 10 half-grown females were removed. The latter died without ovipositing. Of the former, 48 deposited eggs in number less than normal. At the same time 40 engorged or nearly engorged females and 30 half-grown females were removed from undipped cattle. All of the former and 3 of the latter deposited eggs.

Four days after dipping 15 engorged females and 12 one-third to one-half grown females were removed from the dipped cattle. None of the latter deposited eggs. Six of the former deposited eggs in number less than normal. On the same date 15 engorged females and 12 one-third to one-half grown females were removed from undipped cattle. All of the former and none of the latter deposited eggs.

Six days after dipping 12 engorged females and 7 one-third to one-half grown females were removed from the dipped cattle. Three of the former deposited eggs in number less than normal and none of the latter deposited eggs. On the same date 12 engorged or nearly engorged females and 7 one-third to one-half grown females were removed from undipped cattle. All of the former and none of the latter deposited eggs.

The ticks which had been removed from the cattle and eggs which they had deposited were sent to the laboratory of the Zoological Division at Washington in the early part of December. They were in such poor condition when received that it was considered useless to make any further observations upon them.

Nymphs.—Two days after dipping 15 nymphs were removed from the dipped cattle. All of these died without molting. On the same date 20 nymphs were removed from undipped cattle. Two of these molted, the others died without molting.

Four days after dipping 15 nymphs were removed from the dipped cattle. Two of these molted, the others died without molting. On the same date 15 nymphs were removed from undipped cattle. Three of these molted, the others died without molting.

Six days after dipping 4 nymphs were removed from the dipped cattle. All died without molting. On the same date 4 nymphs were removed from undipped cattle. All died without molting.

EFFECT OF REPEATED APPLICATIONS OF THE ARSENIC, SODA, AND PINE-TAR DIP.

Experiment No. 22.

This experiment, though not concerned with the efficacy of arsenical dips, may be recorded here inasmuch as it has a bearing upon the question of the injurious effects of these dips upon cattle.

Beginning June 23, 1910, 2 lots of calves of 3 head each were dipped repeatedly at intervals until near the end of October. A third lot of 3 was kept under observation undipped. All 3 lots were kept together in the same yard and stable at the Bureau Experiment Station under the same conditions except as to dipping.

Lots A and B were dipped June 23 in a dip made from 7 pounds of arsenic trioxid, 6½ pounds of sodium carbonate (anhydrous), 0.7 gallon of pine tar, and sufficient water to make a total of 350 gallons.

This dip contained sodium arsenite equivalent in amount to 0.217 per cent arsenic trioxid.[1]

One week later lot A was dipped again in the same dip and thereafter was dipped every two weeks until October 20, when the last dipping was made. At the last dipping a freshly prepared dip was used, which was mixed in the same proportions as the dip made in June, and contained sodium arsenite in solution equivalent to 0.22 per cent arsenic trioxid.[2]

Lot B was dipped every three weeks after the first dipping, using the dip made June 23. The last dipping was made on October 27. At this dipping the freshly prepared dip made October 20 was used.

The cattle of lot A were accordingly dipped 10 times and those of lot B 7 times. Each animal when dipped was kept in the bath 2 minutes. Once a week the cattle were weighed and examined.

One week after the first dipping 5 of the 6 animals dipped showed a slight scurfy condition of the skin on different parts of the body, but no irritation. The hair was rather dry and rough.

Two weeks after the first dipping and one week after the second dipping, one of the cattle in lot A showed a moderate dandruff-like exfoliation on the neck, inner side of thighs, and the flank. Another showed some roughness of the skin on the inner side of the thighs and the third showed a very slight roughness of the skin in the same location. One of the cattle in lot B, two weeks after dipping, showed considerable epidermal exfoliation of a dandruff-like character on the brisket and inner side of thighs. Another showed a very slight roughness on the inner side of one thigh, and the third a rough exfoliation on the inner side of both thighs.

Three weeks after the first dipping and two weeks after the second dipping, one of the cattle in lot A had a slight scurf in the hair on the brisket and on the elbows. Another showed a slight roughness of the skin on the inner side of the thighs. The skin of the third calf was normal. On the same day one of the animals of the other lot which had been dipped 3 weeks before was scurfy on the brisket, and the skin on the inner side of the thighs was slightly rough. Another had a slight loose scurf on the inner side of the thighs, and the third showed some scurf and scale on the inner side of thighs, peeling off with slight loss of hair.

By August 4 all evidences of any injurious action of the dip on the skin of the dipped animals had disappeared, and no signs of any action of the dip on the skin were thereafter observed except that at times the hair of the dipped animals appeared to be somewhat dryer than that of the undipped animals. The freshly prepared dip used at the final dipping had no noticeable effect upon the skin. During the progress of the experiment the cattle of all three lots became more or less affected with ringworm, upon which the dip had no apparent effect.

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[1] Analysis made in Biochemic Division of a sample taken June 23.

[2] Analysis made in Biochemic Division.

July 29, one of the cattle in lot C, the undipped lot, died. The lungs were pneumonic with many lung worms present.

August 13, one of the animals in lot B died after symptoms of pneumonia. On post-mortem the lungs were found to be in a pneumonic condition, and the trachea was occluded with a mass of lung worms.

Other calves in the three lots of cattle presented symptoms from time to time suggesting the presence of lung worms, but the two just referred to were the only ones which died. Another calf was added to lot C to take the place of the one which died, but lot B was continued after August 13 with only two calves.

The three calves in lot A on June 23 weighed 172.5 pounds, 210 pounds, and 235 pounds, respectively, and on November 3, at the close of the experiment, 240, 260, and 315 pounds, respectively. The two calves in lot B which survived weighed, respectively, 215 and 242.5 pounds at the beginning of the experiment and 285 and 365 pounds at the end of the experiment.

The two surviving calves of the three original animals in lot C, the undipped lot, weighed, respectively, 232.5 and 342.5 pounds at the beginning of the experiment and 415 and 570 pounds at the end of the experiment. The calf substituted for the one that died weighed 180 pounds August 4 and 240 pounds at the close of the experiment. At times the animals in all three lots fell back in weight, but on the whole they showed a gradual increase from first to last.

From the foregoing figures it is seen that the average gain in weight of the cattle in lot A was 32 per cent, in lot B 42 per cent, and in the undipped lot C, assuming that the substitute calf gained 30 pounds from June 23 till August 4, when it entered the experiment, 68 per cent. Apparently the gain in weight was diminished as a result of dipping, but the number of cattle in the experiment was too small for any definite conclusion to be drawn in regard to this point. The fact also that some of the cattle were suffering more or less from lungworm infection is a factor which would affect the validity of any general conclusion that might be drawn from this experiment as to the relative gain in weight shown by cattle repeatedly dipped in arsenical dip, as compared with undipped cattle.

In view of the oxidation of the dip used in the present experiment which began to occur at some time subsequent to the third dipping of lot A and the second dipping of lot B, the value of the experiment is less than it would have been had freshly made dips been prepared from time to time. The effects of repeated applications of freshly made dips might, of course, have proved more serious than those which occurred as a result of the repeated use of the oxidized dip. The experiment was therefore unsatisfactory so far as concerns the question as to the amount of injury to cattle which may be expected when they are dipped repeatedly at intervals of two to three weeks during a period of several months in an arsenic, soda, and pine-tar dip containing sodium arsenite equivalent to 0.22 per cent arsenic trioxid.

DISCUSSION OF RESULTS.

EFFECTS OF ARSENICAL DIPS ON CATTLE.

The effects of the dips upon the cattle in the various experiments were almost invariably slight.

No constitutional symptoms were observed except in one experiment (No. 14), in which a dip containing 0.476 per cent of arsenic trioxid was used, and these may have been secondary to severe skin lesions. The calf dipped in this strong solution lost considerably in weight and did not begin to recover from the effects of the dip until about a month after dipping. In another experiment (No. 16) a calf dipped in a still stronger solution (0.495 per cent) of arsenic trioxid showed no signs of injury other than slight skin injury. Cattle not infested with ticks, dipped repeatedly in a dip containing an equivalent of about 0.22 per cent arsenic trioxid at intervals of two and three weeks gained less in weight than other uninfested cattle kept under the same conditions undipped, but it is uncertain whether this difference was due to the dipping. (See experiment No. 22.)

In all cases in which cattle were dipped or sprayed once or twice in arsenical dips containing an equivalent of from 0.16 to 0.24 per cent arsenic trioxid the injurious effects observed were confined to the action of the dips upon the skin, and scarcely ever was this action more than very mild, though in some cases the animals were treated in hot weather when the injurious effects from dipping are especially likely to appear. The signs of the effects of dipping on the skin in various instances became evident in from 3 to 9 days after the treatment, at which time a more or less well-marked epidermal exfoliation or dandruff-like peeling of the superficial layers of the skin appeared, confined as a rule to the dewlap, neck, escutcheon, inner side of thighs, and scrotum. No marked inflammation preceded the exfoliation, though occasionally a slight irritation of the skin in places was observed.

In a number of cases the skin became somewhat thickened on certain parts of the body, namely on the escutcheon, inner side of the thighs, dewlap, and neck. Rarely was cracking of the thickened skin observed. In one experiment (No. 13) in which cattle were sprayed once with an arsenical solution containing an equivalent of about 0.17

per cent arsenic trioxid to which had been added 10 per cent crude petroleum emulsified with soap, rather severe skin injury was observed in the case of some of the animals, consisting in exfoliation, thickening, and cracking of the skin, with evident soreness, which caused the animals to become stiff and lame. These effects were apparently largely due to the oil, as the skin of cattle sprayed in the same dip before the addition of the crude petroleum showed scarcely any signs of injury (experiment No. 2). In the case of a few animals in some of the experiments a slight loss of hair accompanied the exfoliation. Bulls seemed to be more liable to skin injury than cows and steers. The effects of a second dipping so far as observed were always less than those of the first. When fresh exfoliation occurred as a result of a second dipping given within two weeks after the first, it first became noticeable in from 8 to 13 days after the second dipping.

In this connection it should be noted that it is a matter of common observation and shown very clearly in many of the experiments detailed in this paper, that there is a great difference in the susceptibility of individual animals to the effects of dips applied in the same way and under similar conditions. The skin affections produced by a dip appear also to depend on the method employed in applying it. Watkins-Pitchford[1] has found that an arsenical dip which is satisfactory from the standpoint of its effects on the skin when used as a spray, is entirely too strong when used as a dip.

In our experiments, cattle dipped ten times with an interval of one week between the first two dippings and with an interval of two weeks between the second and third and succeeding dippings and cattle dipped seven times at intervals of three weeks showed scarcely any evidences of the effects of the dip upon the skin (experiment No. 22). The dip used in this experiment originally contained sodium arsenite equivalent to 0.217 per cent arsenic trioxid, but at some time between three weeks and three months after the first dipping the sodium arsenite had become largely oxidized to sodium arsenate. It is probable that sodium arsenate is less active on the skin than sodium arsenite, hence it is possible that if a freshly made arsenical dip had been used at each dipping, the repeated applications might have had more effect upon the cattle, though it should be noted that at the tenth dipping of one lot of cattle, and the seventh dipping of the other lot, a freshly prepared dip containing an equivalent of 0.22 per cent arsenic trioxid was used without producing any noticeable skin injury.

In one experiment (No. 12, lot C) in which a dip, containing an equivalent of 0.222 per cent arsenic trioxid with some soap, was used, the effects on the skin, though not serious, were somewhat more marked than those usually observed following the use of a simple arsenic, soda, and pine-tar dip, containing the same percentage of arsenic. The effects of a proprietary dip, which contained soap and other ingredients of minor importance in addition to arsenic, as observed in two experiments (Nos. 20 and 21), were apparently somewhat greater than those resulting from the above-mentioned dip containing soap or the ordinary arsenic, soda, and pine-tar dip.

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[1] Natal Agricultural Journal, Pietermaritzburg, vol. 12 (4), 1909, pp. 436–459; vol. 15 (5), 1910, pp. 577–602.

The following conclusions may be drawn from the various experiments as to the effects of arsenical dips upon cattle:

Cattle may be safely dipped or sprayed with an arsenical dip containing an equivalent of 0.24 per cent arsenic trioxid or less, and the treatment once repeated seven or more days later,[1] the only injury to be expected as a rule being more or less epidermal exfoliation, and sometimes slight soreness or tenderness of the skin, local in character.

It is understood in stating the foregoing conclusions that accidents resulting from a lack of proper precautions to avoid the drinking of the dip by cattle are excluded from consideration, and it should also be noted that cattle are liable to suffer severely after dipping, especially in hot weather, if driven long distances, or even if allowed to run short distances so that they become overheated. This latter fact is stated on the basis of observations made by various persons who have had considerable practical experience in the use of arsenical dips. On the whole, however, in view of the hundreds of thousands of cattle on farms and ranches which have been treated with arsenical dips under all sorts of conditions, the number of cases of injury reported has been remarkably small.

In this connection it is of interest to note that Watkins-Pitchford[2] in observations made in South Africa, finds that dipping work oxen every fifth day in an arsenical dip called the "Laboratory Dip" (containing as its essential ingredients 8½ pounds of arsenite of soda, 80 per cent arsenic, to 400 gallons (imperial)[3] of water) does not interfere in any way with cattle being worked regularly.

EFFECTS OF ARSENICAL DIPS ON TICKS.

The experiments discussed in the present paper have fully confirmed the observations of various investigators and practical users of arsenical dips who have found that ticks are very sensitive to arsenic. Little is known, however, as to the avenue by which arsenic enters the body of ticks when arsenical dips are used.

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[1] If many treatments are given the intervals between treatments should not be less than two weeks.

[2] Loc. cit.

[3] One imperial gallon equals approximately 1.2 U. S. gallons.

W. F. Cooper[1] states that he has proved "that on the application of an arsenical solution to the skin of a beast, the arsenic penetrated the skin and was to be found in all the tissues of the beast, and further, that this took place very rapidly." In his experiments a considerable amount of arsenic was found in blood taken from the heart as early as eighteen hours after dipping. Contrary to the results obtained by Mr. Cooper, a committee appointed by the board of health, Natal, South Africa (Agricultural Journal of the Cape of Good Hope, vol. 37, No. 6, December, 1910, p. 699), has found that no trace of arsenic was present in the muscles, liver, kidneys, or stomach of cattle dipped repeatedly at short intervals in arsenical solutions. With regard to the presence of arsenic on the coat and in the skin of animals treated regularly with an arsenical dip, Watkins-Pitchford[2] has furnished some interesting observations. He appears to have shown by analysis of samples of skin a foot square from animals that have been dipped or sprayed regularly, that there is an accumulation of arsenic in the skin up to a certain maximum amount which is rather constant and can not be materially raised by shortening the interval between treatments. He believes that there is not merely a mechanical deposition of arsenic in the skin, but that the amount is controlled by vital processes, any excess of arsenic beyond a certain amount being rapidly taken up by the blood and eliminated in the urine. The amount of arsenic in the hair and scurf is raised by spraying the skin immediately after death, while that in the skin, according to the statement of the author, is not, but the evidence presented on this last point is not complete. It was also found that the amount of arsenic in the hair and scurf of a square foot of skin was always greater than that in the skin itself.

The same author has shown by experiments, which, however, are rather limited, that animals that have been treated with an arsenical dip are poisonous to ticks; that this toxicity increases with the number of treatments, and that in regularly treated animals, it is less, in accordance with the length of the period elapsing after the last treatment. It was also found that when infested animals regularly treated and others not thus treated were dipped, the ticks on the former perished much more quickly than on the latter.

That ticks are not killed by arsenic present in the blood, the author claims to have shown by spraying an animal all over, except on a certain area where ticks had been placed, when the ticks remained unaffected. On the other hand, the poisonous effects do not appear to be due to a simple deposition of arsenic on the skin, because when ticks are permitted to attach to an area of skin, in a regularly treated animal, which has been previously shaved and washed to remove any arsenic on the surface, they nevertheless succumb. Some interesting observations were also made with regard to the persistence of arsenic in the hair. In one instance arsenic was found in the hair 6 months and in another 7 months after treatment. A case is referred to in which 3 inches of rainfall did not lower appreciably the amount of arsenic in the coat.

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[1] Journal of Agricultural Science, vol. 3, part 3, p. 288, Cambridge, 1910.

[2] Natal Agricultural Journal, vol. 15 (3), pp. 312-329, Pietermaritzburg, 1910.

Although Watkins-Pitchford's observations indicate that arsenic accumulates in the skin of cattle when they are dipped repeatedly, it is certain that the action of arsenical dips is not entirely dependent upon the arsenic which ticks may obtain from the skin for the reason that ticks removed from cattle immediately after dipping may afterwards exhibit evidences of having been acted upon by the dip. Our slight knowledge of the mechanism of the action of arsenic upon ticks, therefore, allows only the general statement that when arsenical dips are used the poison enters the bodies of the ticks in one or more of the following four ways, namely, (1) through the mouth; (2) through the breathing pores; (3) through other openings of the body; or (4) by absorption through the cuticle. As a corollary to this statement it may be added that the poisonous action of these dips upon ticks is certainly not entirely dependent upon the arsenic which may be ingested indirectly from the skin of cattle after treatment, but is largely, if not chiefly, dependent upon that absorbed or ingested directly as a result of immersion in the dipping fluid.

FEMALE TICKS.

It was noted in the various experiments that, as a rule, after cattle had been treated with arsenical dips the number of female ticks maturing became rapidly less day by day, and that it was exceptional to find any engorged ticks present a few days after the treatment. It is therefore evident that after treatment with an arsenical dip the vast majority of the young adult females die before they reach the engorged stage, and that the younger they are the less likely are they to survive and become engorged.

In six experiments the cattle were found to be free from engorged ticks three to five days after the first treatment, in four other experiments they were free seven to nine days after treatment, in another they were nearly free five days after treatment, in another experiment all that were examined were free from engorged ticks eight days after treatment, and in two other experiments the cattle were nearly free from engorged ticks eight days after treatment. An idea of the marked effect of treatment upon female ticks may be obtained from the observations made in one experiment (No. 5) in which a record was kept of the number of ticks which reached the engorged stage on 2 calves after dipping in an arsenical dip containing an equivalent of 0.16 per cent arsenic trioxid. This dip contained considerably less arsenic than the dips usually employed. A third calf was kept under observation undipped, and the number of ticks maturing on this animal from day to day was recorded, as in the case of the 2 dipped calves. On one of the dipped calves 1,340 ticks and on the other 1,907 ticks reached engorgement during the first week after dipping. From the undipped calf 968 engorged ticks of which a record was kept were collected during the same period. Subsequent to the first seven days after dipping only 67 and 37 ticks, respectively, reached engorgement on the dipped animals, whereas more than a thousand reached full maturity on the untreated calf.

A question of great importance is that of the fate of the ticks which reach engorgement and fall from cattle subsequent to treatment with arsenical dips. In order to obtain data bearing upon this question engorged ticks were collected from the cattle in the various experiments immediately after treatment and on successive days thereafter, and kept under observation. Observations were likewise made upon ticks removed on corresponding dates from untreated cattle. These ticks were kept under the same conditions as those from the treated cattle, and thus served as "controls" or "checks" upon the latter. Excluding from consideration one experiment (No. 5 referred to in the preceding paragraph) in which an unusually weak arsenical dip was used, about 70 lots of ticks varying in number from 1 to 100 each were removed from treated cattle in the various experiments. A somewhat smaller number of lots of ticks from untreated cattle were kept under observation as controls, as in several cases the same lot of ticks from untreated cattle was utilized as a control for several lots from treated cattle. Reviewing the observations recorded relative to the ticks removed from cattle, it may be noted that whereas in many of the lots from treated cattle all of the ticks died without ovipositing, in most cases some of the ticks deposited eggs, the percentage of ticks ovipositing usually being low although in rare instances as high as 100 per cent (Tables 1 to 7, column 4). In the control lots the number of ticks ovipositing was almost always 100 per cent (Tables 1 to 7, column 8).

A marked difference is also apparent with reference to the number of eggs deposited by ticks from treated and from untreated cattle. Ticks from treated cattle which survived to deposit eggs nearly always deposited a much smaller number than ticks from untreated cattle (Tables 1 to 7, columns 5 and 9).

Moreover, not only were the eggs deposited by ticks from treated cattle less numerous but they rarely hatched. On the other hand in only one instance among the control lots did all the eggs fail to hatch (Tables 1 to 7, columns 6 and 10). This was due to the lack of proper moisture, and the same circumstance explains the rather low percentage of eggs which hatched in several other control lots. In great contrast to the high percentage of eggs hatching among those deposited by ticks from untreated cattle, is the fact that out of approximately 70 lots of ticks[1] from treated cattle only 4 lots deposited eggs which hatched. The data concerning these 4 lots of ticks are as follows: Three ticks, removed from cattle immediately after spraying with a dip containing an equivalent of 0.217 per cent arsenic trioxid but in which the sodium arsenite had become largely oxidized to sodium arsenate, deposited eggs of which 5 per cent hatched (experiment No. 12). Twenty out of 48 ticks removed from cattle two days after dipping in a dip containing an equivalent of 0.202 per cent arsenic trioxid deposited eggs of which 1 per cent hatched (experiment No. 20), and in the same experiment 10 out of 22 ticks removed three days after dipping deposited eggs of which less than 1 per cent hatched. The fourth case was that of a tick removed from a calf four days after dipping in a dip containing an equivalent of 0.215 per cent arsenic trioxid. This tick deposited numerous eggs about half of which hatched (experiment No. 6). Judging from these results it would appear that the hatching of eggs deposited by ticks which survived treatment with arsenical dips is a rather rare occurrence. Furthermore, it has been noted that the larvæ from eggs deposited by females which have been subjected to arsenical solutions are frequently in such a weakened condition that they can not emerge from the eggshell, or they may become lodged in the opening of the ruptured shell and fail to extricate themselves, or show such slowness of movements after emerging as to make one believe that they could not effect a successful attachment after reaching a host, a condition of the larvæ which has also been noticed in the case of eggs subjected to unfavorable conditions, such as a low relative humidity and low temperatures.

The data relative to the ticks removed from cattle after treatment and their corresponding controls from untreated cattle given in the account of the various experiments are summarized in Tables 1 to 7.

In part A of each table are given the data relative to ticks from treated cattle, and in part B the data relative to ticks from untreated cattle, these being removed from their host on corresponding dates and kept under the same conditions as those from the treated cattle. The data for each lot and its corresponding control are given in the same horizontal line.

Column 1. The figures given in this column refer to the number of the experiment to which each lot of ticks belonged.

Column 2. In this column is given the percentage of arsenic, expressed in terms of arsenic trioxid, which was contained in the dip used in treating the cattle from which the ticks were removed.

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[1] This includes all of the different lots of ticks collected from the treated cattle in the various experiments with the exception of experiment No. 5, which is omitted from consideration on account of the fact that the dip used contained an unusually low percentage of arsenic.

Column 3. In this column is given the number of ticks included in each lot removed for observation.

Column 4. The percentage of ticks in each lot which survived to deposit eggs is given in this column.

Column 5. In this column is given the average number of eggs deposited by each tick which survived to deposit eggs. This number was determined either by counting or by weighing the eggs and by calculation from the weight upon the assumption that one egg averages 0.04 milligram in weight.

Column 6. In this column is given for each lot the percentage of eggs hatching.

Columns 7, 8, 9, 10. The data in these columns refer to ticks from untreated cattle and correspond to the data given in columns 3, 4, 5, and 6, respectively.

TABLE 1.—*Results with engorged ticks collected a few hours after treatment.*

A. From treated cattle.						B. From untreated cattle (controls).			
1	2	3	4	5	6	7	8	9	10
Experiment No.	Per cent of arsenic in dip.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.
1	0.204	6	33	Few.	0	8	100	Normal.	95
2	.172	8	88	...do.....	0	6 14	(?) (?)	(?) Normal.	10 Over 50.
3	.217	15	0	0	0	(?)	(?)	...do.....	Many.
6	.215	[1] 57	81	107	0	17	100	1,316	97
		27	37	252	0	1	100	1,065	40
8	0.215-.234	46	2	30	0	40	100	1,336	60
		6	50	728	0				
9	.225	20	85	481	0	6	100	1,083	25
		6	33	328	0				
		[2] 14	79	439	0				
12	[3] .217	11	73	(?)	0	29	100	(?)	40
		3	100	(?)	5				
	.234	37	16	Few.	0				
		2	100	(?)	0				
	.222	59	0	0	0				
		18	0	0	0				
13	.17	38	24	Few.	0	6 14	(?) (?)	(?) Normal.	10 Over 50.
14	.476	49	0	0	0	[4] 25	96	316	12
16	.495	[1] 43	0	0	0	[4] 22	96	505	50
		19	21	81	0				
20	.202	[5] 30	4	(?)	0	[6] 36	(?)	(?)	50
21	.224	100	0	0	0	100	100	(?)	....

[1] Engorged and nearly engorged.
[2] One partially engorged.
[3] Oxidized dip.
[4] Partially engorged.
[5] Twenty partially engorged.
[6] Twenty-five partially engorged.

TABLE 2.—*Results with engorged ticks collected one day after treatment.*

A. From treated cattle.						B. From untreated cattle (controls).			
1	2	3	4	5	6	7	8	9	10
Experiment No.	Per cent of arsenic in dip.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.
6	0.215	[1] 24	21	256	0	17 1	100 100	1,316 1,065	97 40
8	0.215- .234	32	25	127	0	40 5	100 (?)	1,336 Numerous.	60 98
9	.225	15 10	80 40	699 322	0 0	12	100	921	10
12	[2].217 .234 .222	29 31 15	86 58 47	(?) (?) (?)	0 0 0	45	100	(?)	75
14	.476	[3] 12	0	0	0	[4] 4	100	853	75
16	.495	[5] 18	17	413	0	[6] 18	100	339	40

[1] Seventeen partially engorged.
[2] Oxidized dip.
[3] Seven partially engorged.
[4] Three partially engorged.
[5] Twelve partially engorged.
[6] Fourteen nearly engorged.

TABLE 3.—*Engorged ticks collected two days after treatment.*

A. From treated cattle.						B. From untreated cattle (controls).			
1	2	3	4	5	6	7	8	9	10
Experiment No.	Per cent of arsenic in dip.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.
1	0.204	14	64	(?)	0	8	100	Normal.	95
6	.215	[1] 17	24	312	0	[2] 8	100	1,464	99
8	0.215- .234	6	67	646	0	5 40	(?) 100	Numerous. 1,336	98 60
9	.225	3 [3] 4 [4] 29	100 50 58	478 419 361	0 0 0	13	100	2,076	1
12	[5].217 .234 .222	8 12 6	88 50 50	(?) (?) (?)	0 0 0	14	100	(?)	4
14	.476	[6] 6	0	0	0	[6] 1	100	737	80
16	.495	[4] 14	14	103	....	[7] 5	100	777	60
20	.202	48 [6] 26	42 19	(?) (?)	1 0	[8] 14	100	(?)	4
21	.224	[9] 60 [8] 10	80 0	Less than normal. 0	....	[9] 40 [8] 30	100 10	Normal. (?)	....

[1] Ten partially engorged.
[2] Three partially engorged.
[3] Three nearly engorged.
[4] Eight nearly engorged.
[5] Oxidized dip.
[6] Nearly engorged.
[7] Two partially engorged.
[8] Partially engorged.
[9] Some only partially engorged.

TABLE 4.—*Engorged ticks collected three days after treatment.*

A. From treated cattle.						B. From untreated cattle (controls).			
1	2	3	4	5	6	7	8	9	10
Experiment No.	Per cent of arsenic in dip.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.
6	0.215	[1] 9	78	612	0	[2] 8	100	1,464	99
8	0.215–.234	9	11	75	0	40	100	1,336	60
						5	(?)	Numerous.	98
9	.225	4	25	637	0	18	94	784	2
		1	100	Very few.	0				
		[3] 11	27	310	0				
12	[4] .217	8	100	(?)	0	8	100	(?)	1
	.234	4	50	(?)	0				
13	.17	34	3	Few.	0	....	....	....	....
16	.495	[2] 6	17	732	0	17	100	1,316	97
						1	100	1,065	40
20	.202	22	45	(?)	1	[5] 14	(?)	(?)	10
		[6] 18	(?)	(?)	0				

[1] Four nearly engorged.
[2] Three partially engorged.
[3] Three nearly engorged.
[4] Oxidized dip.
[5] Thirteen partially engorged.
[6] Partially engorged.

TABLE 5.—*Engorged ticks collected four days after treatment.*

A. From treated cattle.						B. From untreated cattle (controls).			
1	2	3	4	5	6	7	8	9	10
Experiment No.	Per cent of arsenic in dip.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.
6	0.215	1	100	1,400	50	1	100	1,787	98
9	.225	1	100	933	0	7	100	1,323	1
		[1] 4	0	0	0				
12	[2] .217	1	100	(?)	0	2	100	(?)	0
20	.202	[3] 3	0	0	0	[3] 3	(?)	(?)	60
21	.224	15	40	Less than normal.	....	15	100	(?)	....
		[4] 12	0	0	....	[4] 12	0	0	....

[1] Nearly engorged.
[2] Oxidized dip.
[3] Partially engorged.
[4] Less than half grown.

TABLE 6.—*Engorged ticks collected five days after treatment.*

A. From treated cattle.						B. From untreated cattle (controls).			
1	2	3	4	5	6	7	8	9	10
Experiment No.	Per cent of arsenic in dip.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.
2	0.172	5	20	200	0	14	(?)	Numerous.	Over 50
						6	(?)	(?)	10
20	.202	1	0	0	0	[1] 3	100	(?)	95

[1] Two two-thirds engorged.

TABLE 7.—*Engorged ticks collected six days after treatment.*

A. From treated cattle.						B. From untreated cattle (controls).			
1	2	3	4	5	6	7	8	9	10
Experiment No.	Per cent of arsenic in dip.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.
20	0.202	[1] 1	0	0	0	....	....	....	....
21	.224	12	25	Less than normal.	....	[2] 12	100	(?)	....
		7	0	0	....	7	0	0	....

[1] Not more than half grown.

[2] Some not fully engorged.

The effects obtained when engorged ticks are taken from untreated cattle and immersed in arsenical dips for a couple of minutes are very much the same as those observed when the ticks are removed from cattle after treatment. (See Table 8.) Sixteen lots, containing from 15 to 123 ticks each, were thus treated. In 5 of the lots none of the ticks oviposited, in the remainder 3 to 100 per cent deposited eggs. In each of the control lots, composed of 4 to 105 ticks each, 95 to 100 per cent of the ticks oviposited. The number of eggs deposited by each treated tick which survived to oviposit averaged much less than in the case of the untreated ticks. In the case of only two lots of treated ticks did any of the eggs hatch. These two lots were treated with a neutral and alkaline solution, respectively, of sodium arsenate equivalent to 0.22 per cent arsenic trioxid, and only 1 and 2 per cent, respectively, of the eggs hatched. In the control lot 99 per cent of the eggs hatched. In view of the close correspondence between the results of the experiments in which engorged ticks were kept under observation after their removal from treated cattle and those in which engorged ticks were removed from untreated cattle and kept under observation after immersion for a short time in arsenical dips, it is evident that experiments of the latter kind are useful in that they furnish an indication of the efficacy of arsenical dips so far as engorged or nearly engorged ticks are concerned.

The arrangement of Table 8 is similar to that of Tables 1 to 7, the data relative to the dipped ticks being given in part A and the data relative to the undipped ticks in part B. The various columns in the table are likewise of similar significance.

TABLE 8.—*Results with engorged ticks dipped in the laboratory.*

A. Dipped ticks.						B. Undipped ticks (controls).			
1	2	3	4	5	6	7	8	9	10
Experiment No.	Per cent of arsenic in dip.	Number of ticks.	Per cent ovipositing.	Number of eggs per tick.	Per cent hatching.	Number of ticks.	Per cent ovipositing.	·Number of eggs per tick.	Per cent hatching.
4	0.213	123	82	712	0	105	100	3,189	99
7	.215	15	0	0	0	8	100	1,464	99
		51	0	0	0	40	100	1,336	60
11	[1].217	16	13	Few.	0	16	100	(?)	40
	.24	16	7	12	0				
	[1].217	15	60	Few.	0	....	....	....	....
	.24	15	0	0	0	....	....	....	....
	[1].217	22	14	Few.	0	22	95	(?)	25
	.24	22	0	0	0				
	.24	21	14	Few.	0	21	95	(?)	75
15	.476	46	4	98	0	46	98	1,443	98
						4	100	853	75
17	.495	59	3	150	0	59	98	1,195	97
18	[2].22	20	95	(?)	1	20	100	(?)	99
	[3].22	20	100	(?)	2				
19	[4].22	22	86	(?)	0	22	100	(?)	1
	.22	22	0	0	0				

[1] Oxidized dip.
[2] Sodium arsenate (neutral).
[3] Sodium arsenate (alkaline).
[4] Sodium sulpharsenite.

No more is known as to the exact way in which the poisonous action of arsenic takes effect upon the eggs of ticks than is known as to the way in which it takes effect upon the ticks themselves. The fact that the eggs have been injured becomes apparent soon after deposition, sometimes immediately. Those which have been injuriously affected are then readily distinguished by their dark color and shriveled condition. The two series of photographs given in Plates I to VI, in which the appearance of treated and untreated ticks may be compared, show very strikingly some of the effects of arsenical dips upon ticks and their eggs.

Summing up the numerous observations which have been made as to the effects of arsenical dips upon engorged, partially engorged, and young female ticks, it will be noted (1) that cattle were generally free from engorged ticks within a week after treatment; (2) that of the ticks which were present in the engorged stage at the time of treatment or which subsequently reached the engorged stage, only a few, as a rule, deposited eggs; (3) that the number of eggs deposited was much less than normal; and (4) that very few of the eggs hatched.

MALE TICKS.

Very few male ticks were found alive on cattle later than a day or two after treatment, and it is probable that most of these were ticks which were in the nymphal stage at the time of treatment. It may therefore be concluded that arsenical dips are highly efficacious so far as the destruction of male ticks is concerned.

NYMPHS AND LARVÆ.

It was found in the experiments with arsenical dips that the vast majority of nymphs were killed by a single treatment. In several experiments, however, some of the nymphs survived and afterwards molted. Supplementing the observations made on nymphs in situ on cattle after treatment, observations were made on nymphs removed from their hosts subsequent to treatment after the lapse of varying periods of time. (See Table 9.) These observations showed that in the case of 12 lots none of the nymphs molted; and that in the case of four lots 8 to 50 per cent molted. Nymphs removed from untreated cattle and kept under the same conditions, as controls, usually molted, 10 to 100 per cent in nine lots, only one lot being collected in which all the nymphs failed to molt.

In Table 9 are given data, summarized from the various experiments, relative to the molting of nymphs removed from cattle after varying periods of time subsequent to treatment, as compared with the molting of nymphs removed on corresponding dates from untreated cattle.

Part A refers to nymphs from treated cattle, and part B to nymphs from untreated cattle removed on corresponding dates and kept under similar conditions.

Column 1. In this column is given the number of the experiment to which each lot of nymphs belonged.

Column 2. In this column is given the percentage of arsenic, expressed in terms of arsenic trioxid, which was contained in the dip used in treating the cattle from which the ticks were removed.

Column 3. The figures in this column refer to the number of days which elapsed from the time the cattle were treated until the nymphs were removed.

Column 4. In this column is given the number of nymphs included in each lot removed for observation.

Column 5. The percentage of nymphs which molted subsequent to removal from their host is given in this column.

Column 6. In this column is given the number of nymphs in each lot removed from untreated cattle.

Column 7. The percentage of nymphs which molted subsequent to their removal from untreated cattle is given in this column.

TABLE 9.—*Results with nymphs collected from dipped and undipped cattle.*

A. From treated cattle.					B. From untreated cattle (controls).	
1	2	3	4	5	6	7
Experiment No.	Per cent of arsenic in dip.	Number of days.	Number of ticks.	Per cent which molted.	Number of ticks.	Per cent which molted.
1	0.204	2	4	50	14	79
		7	13	8		
2	0.172	5	60	0	25	84
		8	7	0		
3	0.217	0	6	33	4	75
13	0.17	14 hours.	10	0	25	84
		3	9	0		
20	0.202	0	12	0	20	95
		2	17	0	2	100
		3	41	0		
		4	54	0	42	64
		5	46	0	12	83
		6	1	0		
21	0.224	2	15	0	20	10
		4	15	13	15	20
		6	4	0	4	0

No instance was observed in any of the experiments of the survival of ticks in the larval stage after a single treatment with an arsenical dip. While the possibility of such an occurrence must be admitted, it seems certain that the survival of larvæ after treatment with an arsenical dip of proper strength would be very exceptional, and for practical purposes it seems safe to assume, until evidence can be obtained to the contrary, that arsenical dips are entirely efficacious so far as concerns ticks in the larval stage.

THE PROTECTIVE ACTION OF ARSENICAL DIPS.

Little evidence has been obtained as to the degree of protection against reinfestation afforded by arsenical dips or as to the length of time after treatment that such protective action continues. It seems, however, that cattle are protected from reinfestation, at least to some extent, during several days after treatment. The results obtained by Watkins-Pitchford with regard to the accumulation of arsenic in the skin and the toxicity of regularly treated animals, already referred to, would seem to show that an arsenical dip may protect cattle considerably against reinfestation. Owing to the uncertainty as to this point, however, it is unsafe to place any reliance upon the protective action of arsenical dips, and it should be assumed that treated cattle are liable to reinfestation if exposed at any time after the arsenical solution has become dry upon their bodies.

PRACTICAL SIGNIFICANCE OF RESULTS OF EXPERIMENTS WITH ARSENICAL DIPS.

In considering the practical application of the results of the experiments with arsenical dips, it should first of all be noted that although arsenic has a marked effect on all stages of the tick, none of the arsenical dips tested has proved sufficiently efficacious to insure a tick-free condition of cattle by means of a single application of the dip. As we know them at present, therefore, arsenical dips must be considered as falling short of the ideal of perfect efficacy.

The question then arises whether with their admitted imperfections arsenical dips may be used with advantage in the eradication of ticks. This question may be unhesitatingly answered in the affirmative. Arsenical dips are undoubtedly of very great value in tick eradication, and all things considered no better dip for the destruction of ticks has yet been discovered. This has been demonstrated not only by experimental work, but also by the results obtained from an extensive practical use of arsenical dips by many owners of live stock in Texas, Oklahoma, and California.

The practical application of the results of the experiments with arsenical dips may be considered under the following heads: (1) Composition of the dip; (2) method of application; (3) number and frequency of applications; (4) handling the cattle.

COMPOSITION OF THE DIP.

The investigations thus far carried out have not been extensive enough to enable a definite statement to be made as to the minimum percentage of arsenic required to give an arsenical dip a sufficiently high degree of efficacy to make it of practical value. Moreover, it is probable that a stronger dip will be necessary to obtain satisfactory results under some conditions than under others, and it is probable also that in many cases a rather weak dip may be used to advantage when a stronger dip would be undesirable on account of possible injurious effects on cattle, as, for example, in the case of repeated treatments during very hot weather.

The experiments indicate that dips containing as high as 0.24 per cent arsenic (reckoned as arsenic trixoid) may be used without unduly injuring cattle. It has been assumed that this is the maximum strength at which dips containing arsenic in the form of sodium arsenite or potassium arsenite may be used without too great risk of injury. In view of the fact that in one experiment (No. 5) an arsenical dip containing somewhat less than an equivalent of 0.2 per cent proved less efficacious than dips in other experiments which contained an equivalent of approximately 0.2 per cent or more of arsenic trioxid, 0.2 per cent was selected as an arbitrary minimum limit. The mean between the minimum and maximum limits, or 0.22 per cent, may therefore be taken as an arbitrary standard, and a dip to have the maximum degree of efficacy, so far as this may be attained without great risk of injury to cattle, should not deviate more than very slightly above or below this standard of 0.22 per cent.

The arsenical dips commonly used and with special reference to which most of the experimental work has been done are based on a modification of Dr. Mayo's formula given in the introduction of the present article. Directions for preparing such a dip so that it will conform to the standard which has been selected are as follows:

> In preparing each 500 gallons of the standard arsenical solution there shall be used 10 pounds of finely powdered white arsenic containing not less than 99 per cent of arsenic trioxid, 25 pounds of sal soda, and 1 gallon of pine tar. The arsenic and sal soda shall be boiled together in not less than 25 gallons of water for fifteen minutes, or longer if necessary to effect complete solution of the arsenic. Before the pine tar is added, the temperature of the solution shall be reduced to 140° F. This may be done by the addition of cold water. The pine tar shall then be added in a small stream while the solution is thoroughly stirred, after which the solution shall be immediately diluted with clear water sufficient to make 500 gallons of dip.

The cooling of the arsenic and sal soda solution before the addition of the pine tar is important, as otherwise an imperfect mixture having a curdled appearance is likely to result.

It has already been noted that the quantity of sal soda used in the above formula is in excess of the amount actually needed to combine with all the arsenic, but until it can be shown that the efficacy of the dip in no way depends upon the presence of this excess of soda, the proportionate amount of sal soda should not be reduced.

In cases wherein it is considered expedient to use a weaker dip the amount of arsenic may be reduced to 8 pounds per 500 gallons of dip, but for all official dippings the standard amount of 10 pounds to 500 gallons is required.

METHOD OF APPLICATION.

There are two practicable methods of applying arsenical dips, namely, by spraying and by dipping.

Spraying is not practicable except in the case of very small herds, unless a spraying machine is used. Spraying machines, however, have proved less satisfactory than dipping vats, and it is therefore preferable to use a dipping vat whenever more cattle are to be treated than it is practicable to treat by means of hand spray pumps. Hand spraying is not only more tedious than dipping, but it is also less efficacious, as there is not the same certainty of getting a thorough application of the dip even when the greatest care is used. Consequently the dipping vat is much more reliable than the spray pump. It is also more economical whenever more than a very few animals are to be treated.

A dipping vat for cattle should be large enough to afford a bath at least 5½ feet in depth, and unless the cattle when dipped are held in the bath, the vat should measure at least 40 feet in length at the surface of the dip. If a shorter vat is used the cattle should be held in the bath at least 15 seconds—half a minute would be better—otherwise they are liable to get through the bath without being thoroughly wet to the skin, particularly if the hair is long. A steep slide at the entrance of the vat is desirable in order to insure a plunge which will carry the cattle entirely under the surface of the bath.[1]

NUMBER AND FREQUENCY OF APPLICATIONS.

From the data obtained in the experimental work it appears that one treatment with an arsenical dip is insufficient to free cattle from ticks. Subsequent to dipping, ticks continue to reach engorgement and fall from the cattle for several days and a few nymphs are liable to survive, molt, and possibly continue their development to the engorged stage. On the other hand, no instance has been recorded in which a tick survived and reached fertile maturity after two thorough applicat ons of an arsenical dip given 7 to 10 days apart, and no larvæ have been observed that have survived a single treatment. The results of the experiments therefore show that cattle may be freed from ticks by two treatments with an arsenical dip.

Although the possibility of ticks surviving two treatments and maintaining the ability to reproduce is always present, the experimental work shows that such an occurrence must be very rare, provided the treatments are thorough, and it is therefore proper to assume, as a working basis, that two treatments are entirely efficacious. Accordingly it may be stated as a tentative conclusion that after two thorough treatments cattle may be placed on uninfested ground with practically no danger of carrying with them any ticks capable of perpetuating the species. In practice, therefore, when cattle are to be treated for the purpose of ridding them of ticks so that they may be put in uninfested pastures or other tick-free places, they should be dipped twice with an interval of 7 to 10 days between dippings, using a full-strength arsenical dip.

When cattle are to continue occupying the same pasture or range the question of the number and frequency of treatments is somewhat different. In this case the rule would be to give repeated treatments at intervals of not over three weeks. Usually more than three weeks and rarely less than this time is required for larval ticks after reaching a host to complete their development to the engorged stage. Hence if cattle were treated every three weeks practically all of the ticks which they picked up in the meantime would be subjected to treatment. Scarcely any would escape and deposit eggs, and when it is considered that the average number of eggs deposited by each tick surviving treatment would be less than normal, and that only a small proportion would hatch, it is evident that the amount of infestation of cattle and pastures would greatly and rapidly diminish. Practical experience has demonstrated that complete eradication may be accomplished in this way, the probable explanation being that even if ticks occasionally survive dipping the number is reduced below the minimum necessary to insure the survival of the species. In other words, in those localities where ticks are established, their fecundity is sufficient for the perpetuation of the species under ordinary conditions, but if the vast majority of individuals that find a host are destroyed, a point is soon reached in the numerical reduction below which it is impossible for the species to maintain itself. No set rule can be formulated at present as to the number of times it will be necessary to repeat the treatment with the arsenical dip to bring about eradication, but a general rule would be to continue the treatment until the ticks had apparently disappeared, then discontinue it, and if at any time ticks are again observed, resume the treatment, keeping always on the lookout for signs of ticks, just as a physician, in the case of diseases liable to reappear when apparently cured, watches for symptoms indicating a recurrence of the malady.

---

[1] The Bureau of Animal Industry is prepared to furnish plans and specifications for dipping vats to persons contemplating the construction of vats.

HANDLING THE CATTLE.

Cattle should not be treated with arsenical dips when tired or thirsty, and after treatment should not be allowed to drain in places where the drippings from their bodies will form pools which they may drink, or where grass or fodder will become soaked with the dip. For a week or so after treatment, especially in hot weather, cattle should not be driven hard or allowed to run or become overheated. After treatment cattle may, however, be safely shipped by rail, even though they are loaded as soon as their bodies become dry.

When cattle are to be freed from ticks by two treatments a special arrangement of the dipping plant and yards for handling the cattle is necessary, so that after the second dipping they will not be exposed to reinfestation. Certain yards and the alleyways leading to them from the draining pen must be reserved exclusively for cattle which have been twice dipped. These yards and alleyways must be free from infection and must not be used for any cattle except those which have been twice dipped or are known to be free from ticks. For several days after the first dipping cattle are likely still to harbor ticks able to reproduce, hence it is unsafe to place them in yards or pastures which it is desirable to keep free from infection, and as the second dipping will destroy any larvæ which they may pick up in the meantime, cattle should be kept between dippings in places which are either definitely known to be infested, or which it is not desired to be kept free from ticks. After the second dipping, however, cattle must be guarded from exposure to infection, hence from the time they leave the draining pens they must not pass over or occupy any places infested with ticks. In order thus to handle cattle either two dipping vats will be required, or, if the same vat is used for both dippings, some arrangement must be made whereby cattle may be brought from the draining pens to their respective yards after the first and second dippings by entirely distinct routes. This may be readily done when a single draining pen is used if the two alleyways for once-dipped and twice-dipped cattle, respectively, lead away in different directions from the draining pen. If, however, the common type of double draining pen is used it will be necessary to add a third section (as shown in the plan) in order that separate routes for once-dipped and twice-dipped cattle may be provided for.

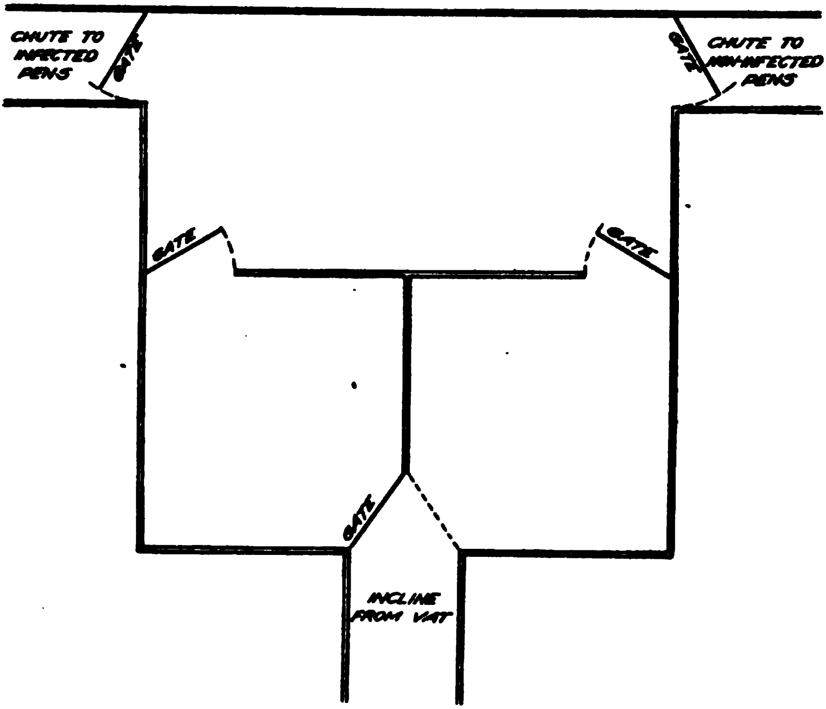

FIG. 1.—Plan of draining pen for cattle after dipping.

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BUREAU OF ANIMAL INDUSTRY.—BULLETIN 145.

A. D. MELVIN, CHIEF OF BUREAU.

TRYPANOSOMA AMERICANUM,

A COMMON BLOOD PARASITE OF AMERICAN CATTLE.

BY

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Junior Zoologist, Zoological Division.

WASHINGTON:
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., August 31, 1911.

Sir: I have the honor to transmit, and to recommend for publication in the bulletin series of this bureau, the accompanying manuscript entitled "*Trypanosoma americanum*, a Common Blood Parasite of American Cattle," by Howard Crawley, of the Zoological Division.

A preliminary description of this trypanosome was prepared in 1909 by Mr. Crawley and published in Bulletin 119 of this bureau. The present paper presents a more extended study of the organism, which is shown to be harbored by about 75 per cent of adult cattle.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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TRYPANOSOMA AMERICANUM, A COMMON BLOOD PARASITE OF AMERICAN CATTLE.

INTRODUCTION.

In Bulletin 119 of the Bureau of Animal Industry there was described, under the name of *Trypanosoma americanum*, a flagellated organism which appeared in bouillon cultures of the blood of American cattle. At the time of writing, although but 7 cows had been tested, trypanosomes had appeared in the blood cultures of all of them, thus indicating that a large proportion of cattle are infected.

The study therein described had been made primarily on stained smears, and based on what was observed in these it was stated that the earliest stage noted was a round or oval body, occurring in clusters, and, while it showed a kinetonucleus, it lacked a flagellum. This last observation is incorrect, the mistake being due to the fact that in these early stages the flagellum fails to stain. A more extended study, based partly on fresh material, has shown that the organisms in the culture tubes are always flagellated. It is desired to emphasize the fact that this observational error was made, since the precise nature of the earliest organism to appear in the culture tubes is a matter of some moment, bearing as it does on the problem of what is the nature of the element present in the circulating blood of the cow. It may also be stated here at the outset that the results of this more extended study show that this latter undoubtedly is a trypanosome like that present in the culture tubes, because trypanosomes have been found in the blood itself within a few hours after its removal from the cow.

RÉSUMÉ OF LITERATURE.

There is a very considerable literature on the trypanosomes of cattle, and a number of species have been described as occurring in them. It will not be necessary here, however, to do more than consider that which bears directly on the problem in hand, that is, which treats of trypanosomes presumably similar to *Trypanosoma americanum*.[1] Some of this literature was reviewed in Bulletin 119, but one paper which should have been noted was overlooked, and several have since come to hand. It may, however, be advisable again to refer to Miyajima's work, since this is the point of departure of all the studies on this peculiar trypanosome.

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[1] References to literature are given in the bibliography at the end of this bulletin.

The organism found by Miyajima in cultures made from the blood of Japanese cattle is apparently the same as that found in the United States. Unfortunately Miyajima does not give a detailed description of his parasite, and his figures are not particularly clear. They show, however, that he was dealing with a trypanosome possessing only a very short undulating membrane, and his figure 10, of a division form, shows two granules lying at the same level and in the anterior part of the body. From this it may be concluded that the Japanese form has the characteristic of a kinetonucleus lying very close to the trophonucleus. Further, the length, given as five times the diameter of a red blood cell, or say 30 microns, is in general agreement with what is found here.

Martini (1909), working at Manila, repeated Miyajima's work, and obtained trypanosomes in bouillon culture tubes inoculated with the blood of a calf. He used 2 c. c. of blood to 10 c. c. of bouillon. In one case the trypanosomes appeared in 33 hours. As a rule, however, the period was from 43 to 48 hours. The tubes were kept at a temperature of 26 to 27° C.[1] The trypanosomes, while in general about the size of *Trypanosoma lewisi*, showed great variation in length. Some were only one and one-half to three times as long as the diameter of a red blood cell, but as the cultures aged they became longer, and on the fifth and sixth days forms were present 20 to 25 times the length of the calf's red blood cell.[2] The smallest forms were morphologically the same as the largest. The anterior end of the flagellum showed a little club-shaped swelling. The kinetonucleus lay transversely, the trophonucleus longitudinally, and the former was generally in front of the latter. The parasites grew indifferently in acid or alkaline bouillon. In cultures in acid media, the cytoplasm contained chromatin granules. A chronological transition was not observed, and rudimentary forms were always to be found alongside of those fully developed. Attempts to inoculate monkeys failed.

Commenting on the above, there can be no question that Martini was dealing with the same trypanosome as Miyajima, which is also, in all probability, the one which appears in cultures made from the blood of American cattle.

Wrublewski (1908)[3] describes a trypanosome found in the blood of the Lithuanian bison. He remarks that this species of *Bos* is not a favorable subject for experimentation and hence his material consisted of smears taken from dead individuals. The trypanosomes found ranged in length from 30 to 50 microns. The posterior end is elongated, but terminates bluntly. In some, the middle portion is broad and rounded (compare figs. 13 and 14, this bulletin). In this broad portion are to be found the kinetonucleus and the trophonucleus, the former in front of the latter. The root of the flagellum is broad and may show a knoblike expansion. The free end of the flagellum is also knobbed. Around the trophonucleus are masses of deeply staining granules, and granules may also be found scattered throughout the entire body.

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[1] Cultures made in the Zoological Laboratory of the Bureau of Animal Industry on July 13, 1909, showed trypanosomes July 15, the mean temperature of the laboratory for this period being 27.4° C.

[2] It is to be regretted that Martini has not furnished us with actual measurements. According to his own figures, the calf erythrocytes range in diameter from 4 to 6½ microns, and this would make the largest specimens say 100 to 150 microns long, clearly a gross exaggeration. His figure 12 shows an animal 40 to 45 microns long; that of figure 14 is perhaps 50, and these are the largest which he figures.

[3] This paper was missed at the time of writing Bulletin 119.

In some cases Wrublewski obtained blood sufficiently fresh to show living trypanosomes. They are very energetic, and in hanging drops dash through the red cells with extraordinary velocity, hurling these to one side. The parasite moves with the flagellum in front. The movement is rotatory.

Vladimiroff and Yakimoff (1908) name this trypanosome *Trypanosoma wrublewski*.

Of the several bovine trypanosomes described as occurring in the circulating blood, this comes by far the closest to *T. americanum*. Wrublewski's figures 3, 4, and 5 would answer for specimens of the American species. The most noteworthy distinction is in the motility, *T. americanum* rarely showing a rapid translatory movement. There is no especial reason why the two might not be the same, the parasite properly belonging to the bison and transferred from it to domesticated cattle by natural means. The fact that the parasite is apparently quite abundant in the circulating blood of the bison, and very scarce in that of ordinary cattle, is no argument against their identity. Moreover, the sluggishness of *T. americanum* in culture tubes is no criterion as to how it may behave in the circulating blood, regarding which there is, unfortunately, no information at hand.

Recent studies have shown trypanosomes to be present in a large proportion of cattle in Germany, or at least capable of appearing in cultures made from their blood.

Knuth and Rauchbaar (1910) tested 17 adult cattle and 2 calves, and found 10 of the adults to be parasitized. Later, out of a lot of 9 cattle, 6 were found infected.

Knuth, Rauchbaar, and Morgenstern (1910) found trypanosomes in culture tubes from 7 out of 25 cattle. They note the presence in the tubes of developmental forms and of agglomerations.

Behn (1910 β), culturing cattle blood in the same manner, found flagellated forms on the second day. Furthermore, in smears made from cultures 1 to 2 days old, he found round bodies, in many cases with alveolar protoplasm, which stained an intense blue with Giemsa. These showed one or more large, round nuclei, variable in size and staining red. The bodies varied in size, the largest being nearly as large as a leucocyte. Some were free, others inclosed in white blood cells. Behn appears to consider that the intracellular forms, growing, break open the leucocytes and escape. He bases this view on the fact that in smears from cultures 2 days old the bodies then had attached to them the remnants of disintegrated leucocytes. He proposes the query as to whether he is dealing with a case of phagocytosis or of an evolution of the parasites within the leucocytes, and promises a more detailed study.

No bodies such as the above have been seen in smears made from American cattle, and it is perhaps possible that Behn was dealing with moribund or dead leucocytes.

The same author (Behn, 1910 *a*) refers to the seven animals mentioned by Knuth, Rauchbaar, and Morgenstern. He states that whereas the cultures from these were always positive from the beginning of August until the end of September, after cool weather set in they no longer developed trypanosomes. One of these cows failed to show parasites after September 11. But in a smear of her blood taken August 8 there was found a single trypanosome, remarkable for its unusual breadth.

Behn gives the following measurements:

	Microns.
Posterior end to middle of kinetonucleus	13
Middle of kinetonucleus to posterior end of trophonucleus	4
Trophonucleus	2
Anterior end of trophonucleus to anterior end	24
Length of body	43
Length of free flagellum	12
Total length	55
Maximum width	12

The trypanosome had the body sharply bent. The cytoplasm showed clear spaces and abundant granules. The granules were almost all of the same size and stained reddish to a blue-violet. Around the nucleus the cytoplasm was freer from granules than elsewhere. The kinetonucleus stained a black violet, and lay in a clear region. The nucleus lay transversely, filling the entire width of the body. It stained pale red.

Continuing his studies Behn (1910 *γ*) inoculated a calf with blood from a cow whose blood gave positive cultures, but was negative to direct examination. Eleven days later the blood of this calf was positive to direct examination. For the first few days the trypanosomes seen were of the *Trypanosoma franki* type, but later they took on the appearance of *T. theileri*. Cultures made from the blood of this calf, after the trypanosomes had appeared, were positive.

Knuth (1910) tested by the cultural method the blood of 41 cattle, with the following results:

	Total number tested.	Positive for trypanosomes.
Adult cattle	31	21
Young cattle	7	1
Sucking calves	3	0

Schmitt (1910) also found trypanosomes of the *theileri* type in a Pomeranian cow suffering from Texas fever. These were found in the blood, were rare, and were present for 10 days.

Sergent, E. and E., (1911) made cultures of the blood of 82 cattle killed at the abattoir at Algiers. Trypanosomes were obtained nine times. Division forms were abundant, and subcultures were made. The medium used was bouillon.

Delanoë (1911), at Alfort, made cultures of cattle blood, using 3 c. c. of defibrinated blood in 10 c. c. of bouillon. Six out of the ten animals tested gave positive results, but not all of the cultures made from parasitized animals were positive, indicating the great rarity of the trypanosomes in the blood. The elements found in the cultures were crithidia-like, averaged 50 microns in total length, and the free tip of the flagella was broadened. Chromatoid granules appeared in the cytoplasm only in the old cultures. In a subculture in Nicolle's medium, there were seen very small forms without flagella, flagellated elements 35 microns long, and trypanosomes with a posterior kinetonucleus.

Knuth confirms Behn in the respect that, after the onset of cold weather, animals having given positive results cease to do so. He suggests that this may be due either to the disappearance of the insect carriers or to the failure of the trypanosomes to grow in the tubes in cold weather. Finally, by private correspondence, Knuth has been advised that blood cultures of cattle have been made in a number of laboratories in Germany, Denmark, and Sweden, with the subsequent finding of trypanosomes.

Dudukalov and Dudukalova (1910) report the results of an experimental study on the trypanosome of the cow. The culture media used were (a) bouillon; (b) equal parts of bovine blood and 0.8 per cent NaCl solution;[1] (c) agar. Each tube was inoculated with a few drops of blood. After 3 to 4 days there appeared in the tubes round forms of the parasite, about the size of leucocytes, in many cases occurring in great clusters. On the sixth to seventh days elongated bodies appeared among these round bodies, and on the tenth to twelfth days there were present great numbers of motile trypanosomes provided with long flagella. After 2 to 3 weeks the trypanosomes were present in enormous numbers and were of various sizes and forms. They remained alive in the tubes for 2 to 4 months. Subinoculations were made and carried to the fourth generation. The optimum temperature for the cultures is 10 to 15° R.

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[1] The text says 0.08 NaCl solution, doubtless a printer's error.

With reference to the above papers, the observation of the German authors that the trypanosomes no longer develop in the tubes after the onset of cold weather is confirmed by the studies made here, as will be pointed out later. As to that of the Dudukalovs, it would be of interest to know if the round bodies first found were flagellated. If so, the Russian authors were dealing with a process altogether like that displayed by *Trypanosoma americanum.* The more leisurely development can be explained by the rather low temperature to which their cultures were subjected. It should also be noted that the figures accompanying their original article—the résumé given above having been taken from a review in a less difficult language than Russian—show that they were dealing with a trypanosome morphologically identical with *T. americanum.* On the other hand, it was not possible to get the American trypanosome to develop in salt solution, even though an equal bulk of blood had been added.

Stockman (1910) found trypanosomes in the blood of 6 out of 10 cattle which had been inoculated with *Piroplasma* to immunize against piroplasmosis. In one case the trypanosomes were present for eight days; in the other five for only a day or two. The trypanosomes were morphologically indistinguishable from *T. theileri,* and would not grow in culture tubes.

Stockman makes no comment, but there is no reason for regarding what he found as anything but *T. theileri,* rendered more abundant as a result of the weakened condition of the cattle.

METHOD OF THE EXPERIMENTAL WORK.

The procedure followed was to prepare cultures of the blood of the cattle, and to examine fresh or fixed preparations made from these. The method of drawing the blood, making the cultures, etc., has been described in Bulletin 119, and need not be repeated here. The study falls easily into two parts, (1) that of the cultures themselves, or what may be called the experimental work, and (2) that made with the microscope on fresh or stained material. The work with the cultures will be detailed first.

EXAMINATION OF CULTURES.

In all, several hundred cultures were made. The media used were beef bouillon, mutton bouillon, bouillon made from extract of meat, and salt solution. In some cases the cultures were made the same day as the blood was drawn; in others an interval of from one to several days was allowed to elapse, the blood meanwhile being kept either in the ice chest, in the laboratory, or in the incubator. Further, the blood was sometimes used in measured quantities; in other cases there was merely added to the medium what was considered to be a sufficient amount.

At first the cultures were in some cases placed in the incubator, but the behavior of *Typanosoma americanum* is here the same as that of any other trypanosome in culture, and cultures kept at incubator temperature quickly deteriorate. The explanation has been advanced that the preference of a "cultural" form for a moderate temperature is due to the fact that the biting arthropod which removes it from the mammalian host has the temperature of the surrounding air. Without dogmatizing as to whether or not this may be true, it is perfectly evident that the reason *T. americanum* can not live in cultures in the incubator is because these cultures spoil. Apparently, without reference to the presence or absence of bacteria, the hemoglobin leaches out of the red cells and goes into solution in the medium, and there can be no doubt that the liquids in the tube undergo profound chemical changes. Hence, in a very great majority of cases, the cultures were kept at room temperature, which varied from 20 to 27.5° C., according to the time of year.

In the greater number of cultures the medium used was neutral beef bouillon, prepared in the laboratory. The tubes were charged the same day the blood was drawn, and the quantity of blood, while not measured, varied from 1 to 4 c. c. The quantity of bouillon was not measured accurately, but ranged from 3 to 6 c. c. It was mainly from such cultures as these that the material used in the microscopical studies was obtained.

It is not necessary to tabulate the results obtained from this lot of cultures, as such. The more interesting results were obtained from those experiments in which the quantity of blood was measured and from those carried out with reference to the season of the year. The former are necessarily an entirely different set from those in which the blood was not measured, and the latter set was made up of both measured and unmeasured cultures. Tables for both of these sets of tubes are given later.

It is evident that in order to determine the number of days required for the trypanosomes to appear in a tube, the tube must be examined daily from the time of making until the trypanosomes appear. This was done for 53 tubes, taken throughout the year, and it was found that the average time required was 3½ days. It is understood that this means the time required for the presence of trypanosomes on the top of the column of red cells to be determined or at least suspected, merely by the use of a hand lens, although in almost all cases this diagnosis was confirmed by the use of the microscope. This average of 3½ days is based on cultures made the day the blood was drawn and which were kept at room temperature.

In all 30 animals were used, and 64 separate tests were made of their blood. Of these animals 27 were yearlings or adults and 3 were young calves. The calves, one of which was but 1 day old, were all negative. The mother of the 1-day calf, tested at the same time, was positive, an indication that trypanosomes can not pass the placenta.

Of the 27 adult animals, 7 gave negative results, hence 74 per cent were infected. The actual figure, however, is probably higher than this, since a single test may be negative merely by accident, and of these 7 cattle, 5 were tested but once. Moreover, as will be shown, the time of year must be taken into account.

The following were six of the cattle which proved negative, with the month when the test was made; the seventh, No. 685, is dealt with below: Nos. 666 and 668, tested in March; No. 667, tested in April; No. 739, tested in May and also in October; No. 536, tested in July; and No. 738, tested in October.

By October the trypanosomes have become much less abundant in the blood, and an animal negative in that month might readily have been positive in July or August. Nevertheless, certain cattle do not harbor the trypanosomes, as the following history of cow No. 685 shows:

Date.	Number of cultures made.	Result.
1909.		
July 13	5	All negative.
July 20	4	Do.
Aug. 18	3	Do.
Aug. 26	Received in the jugular vein 20 c. c. of blood from cow No. 689, known to carry trypanosomes.	
Aug. 30	3	All negative.
Sept. 2	3	Do.
Sept. 8	3	Do.
Nov. 17	6	Do.

This is apparently a case of natural immunity. The inoculation might have failed, but the constant negative findings for five months, including the greater part of the hot season, show that the animal was able to resist natural infection. There was nothing in the history of this animal to differentiate it from any other, and it was in precisely the same environment as all of the other cattle at the Experiment Station. In fact, both it and No. 689, from which it was inoculated, were kept for a part of the summer in the same pen.

SEASONAL VARIATION IN NUMBER OF TRYPANOSOMES IN BLOOD.

The seasonal variation in the abundance of trypanosomes is very well shown by the history of cow No. 218, as follows:

Appearance of trypanosomes in cultures from cow No. 218.

No. of culture.	Date.	Quantity of blood.	Time required for trypanosomes to appear.	Remarks.
244	Aug. 18	Not measured.[1]	4 days	
245	do.	do.	5 days	
294	Aug. 31	do.	6 days	Blood kept on ice 1 day.
295	do.	do.	4 days	Do.
299	Sept. 1	do.	5 days	Blood kept on ice 2 days.
303	Sept. 2	do.	do.	Blood kept on ice 3 days.
309	Sept. 3	do.	4 days	Blood kept on ice 4 days.
330	Sept. 8	do.	3 days	
331	do.	do.	2 days	
334	do.	do.	do.	
420	Nov. 17	1 c. c.	Negative	
421	do.	2 c. c.	do.	
422	do.	3 c. c.	do.	
423	do.	4 c. c.	do.	Contaminated.
424	do.	5 c. c.	do.	
425	do.	6 c. c.	6 days	
426	do.	7 c. c.	Negative	
427	do.	8 c. c.	6 days	
428	do.	9 c. c.	do.	
429	do.	10 c. c.	do.	
436	do.	1 c. c.	Negative	
438	do.	3 c. c.	do.	
440	do.	5 c. c.	6 days	
441	do.	6 c. c.	Negative	
442	do.	7 c. c.	10 days	
443	do.	8 c. c.	Negative	
445	do.	10 c. c.	5 days	

[1] From 1 to 4 c. c., probably averaging 3 c. c.

From this table we see that in August and September the cultures were all positive, and some showed trypanosomes as early as the second day. On the other hand, of the 17 cultures made in November, only 7 were positive, with 5 days as the minimum time. Moreover, while the average quantity of blood used in August and September was probably about 3 c. c., and in no case exceeded 4. c. c., the least quantity to develop trypanosomes in November was 5 c. c., and one each of the cultures containing 7 and 8 c. c., respectively, were negative.

In the case of cow No. 697, from which many cultures were made, it was found that a larger proportion of tubes were positive, and trypanosomes appeared more quickly in spring and summer than they did in the autumn.

The table following shows all the cases where the time of appearance of the trypanosomes was determined. It gives the number of cultures so determined, the maximum and minimum time required for the trypanosomes to appear, in days, and the average of the whole number. There is also given the mean temperature of each month, as obtained at the Washington, D. C., station of the United States Weather Bureau, and the mean temperature of the zoological laboratory.

Time of appearance of trypanosomes in laboratory cultures, by months.

Month.	Number of tubes.	Time of appearance.			Temperature.	
		Maximum.	Minimum.	Mean.	Washington.	Laboratory.
1909.		*Days.*	*Days.*	*Days.*	*°F. °C.*	*°F. °C.*
April	15	4	3	3.3	54.2—12.3	72.5—22.5
May	12	3½	1½	3.0	64.4—18.0	74.3—23.5
June	1	3	3	3.0	73.4—23.0	78.7—25.9
July	11	4	2	3.3	74.7—23.7	81.5—27.5
August	13	6	3	4.4	73.0—22.8	79.1—26.2
September	6	6	2	3.3	66.4—19.1	75.2—24.0
October	12	8	7	7.2	53.2—11.8	70.4—21.4
November	15	9	3	6.2	50.8—10.4	71.7—22.1
1910.						
March	8	6	2	4.1	51.2—10.7	74.4—23.6
April	15	4	3	3.3	57.9—14.4	74.1—23.4

The reason why the laboratory temperature is always higher than that of the open air is doubtless obvious enough, although attention may be called to the fact that in hot weather the closing of the laboratory windows at 4.30 p. m. prevents any such nightly fall of temperature as is usual in the open. The temperature as recorded by the Weather Bureau, although taken in the city itself, may be assumed to correspond to that of the Experiment Station of the Bureau of Animal Industry, the home of the cattle. Accordingly, the one column shows the fluctuations of temperature to which the animals harboring the trypanosomes were subjected, the second that in which the tubes were kept. The former can hardly be supposed to have any influence, since a mammal maintains its own temperature without reference to that of the surrounding air. Therefore in making comparisons between the rates of growth of the trypanosomes at different times of the year, it is the temperature of the laboratory which should be taken into account and not that of the open country.

In the following, taken from the table given above, the months are in the first two cases grouped with reference to uniformity of temperature and in the last with reference to the time required for the cultures to develop.

1. *Variation in time of appearance of trypanosomes although monthly temperatures are closely uniform.*

Month.	Laboratory temperature.	Mean time of appearance.
	°F.	*Days.*
April, 1909	72.5	3.3
November, 1909	71.7	6.2
October, 1909	70.4	7.2

2. *Uniformity in time of appearance of trypanosomes in spring months.*

Month.	Laboratory temperature.	Mean time of appearance.
	°F.	*Days.*
March, 1910	74.1	4.1
April, 1910	74.4	3.3
May, 1909	74.3	3.0

3. *Uniformity in time of appearance of trypanosomes although variation in monthly temperatures is considerable.*

Month.	Laboratory temperature.	Mean time of appearance.
	°F.	*Days.*
April, 1909	72.5	3.3
May, 1909	74.3	3.0
July, 1909	81.5	3.3
September, 1909	75.2	3.3
April, 1910	74.1	3.3

In the first group it is seen that although the temperatures are very close, the time required in one case is more than double that of another. In the second group the maximum difference in time is only 1.1 days, but here the comparison is between the three spring months. In the third, although the times are so near alike that the difference is negligible, there is a maximum difference of 9° F. in the temperature.

In the statement below the entire time during which the study was being carried on is divided according to the three seasons—spring, summer, and autumn. The average time required for the cultures to develop during each season is computed, due weight being given to the number of cultures used, and the mean temperature, both of the open country and the laboratory, are given.

Time of appearance of trypanosomes according to seasons.

Season.	Time of appearance.	Mean temperature.	
		Outside.	In laboratory.
	Days.	*°F.*	*°F.*
Spring	3.39	56.9	73.8
Summer	3.86	73.7	79.8
Autumn	6.04	56.8	72.4

There is seen here a considerable seasonal difference in the time required for the trypanosomes to appear in the tubes. This is taken to be an index to their abundance. The mode of examination of the cultures was throughout much the same, namely, a preliminary observation of the top of the column of blood cells with a hand lens, followed, when necessary, by the examination of a drop of the culture under the microscope. The latter was undertaken only when the former left the question as to the presence or absence of trypanosomes in doubt.

As we shall see later, multiplication of the trypanosomes begins as soon as the blood containing them is removed from the cow. It therefore seems reasonable to regard their discovery in the culture tubes by means of the procedure indicated above as evidence of greater abundance rather than a mere rapid multiplicative rate. Hence it is believed that these figures furnish satisfactory evidence to show that whereas the trypanosomes are less abundant in autumn than in spring or summer, this difference is independent of temperature. The figure for spring is also lower than that for summer, but this difference is not large enough to warrant any conclusions.

EFFECT ON THE TRYPANOSOMES OF KEEPING BLOOD BEFORE CULTURES WERE MADE.

The following table gives the results obtained when the blood was kept one or more days before the cultures were made. The several columns show, in order, the number of the cow; date culture was made; date blood was drawn; interval in days; number of tubes used; number of tubes giving positive results; and place where blood was kept.

Result of examination of laboratory cultures for trypanosomes.

No. of cow.	Culture made.	Blood drawn.	Interval (days).	Number of tubes.	Number of positive cases.	Place blood was kept.
	1909.	1909.				
688	Apr. 2	Mar. 31	2	3	0	On ice.
696	May 7	May 2	5	5	0	Do.
688	Aug. 19	Aug. 17	2	4	0	In laboratory.
689	Aug. 27	Aug. 26	1	2	0	Do.
218	Aug. 27	Aug. 26	1	2	0	Do.
689	Aug. 28	Aug. 26	2	2	0	Do.
218	Aug. 28	Aug. 26	2	2	0	Do.
689	Aug. 29	Aug. 26	3	2	0	Do.
218	Aug. 29	Aug. 26	3	2	0	Do.
689	Aug. 30	Aug. 26	4	2	0	Do.
218	Aug. 30	Aug. 26	4	2	0	Do.
689	Aug. 31	Aug. 26	5	2	0	Do.
218	Aug. 31	Aug. 30	1	2	0	In incubator.
218	Aug. 31	Aug. 30	1	2	2	On ice.
218	Sept. 1	Aug. 30	2	2	0	In incubator.
218	Sept. 1	Aug. 30	2	2	1	On ice.
218	Sept. 2	Aug. 30	3	2	0	In incubator.
218	Sept. 2	Aug. 30	3	2	1	On ice.
218	Sept. 3	Aug. 30	4	2	0	In incubator.
218	Sept. 3	Aug. 30	4	2	1	On ice.
696	Sept. 4	Sept. 3	1	2	0	In laboratory.
697	Sept. 4	Sept. 3	1	2	2	Do.
696	Sept. 5	Sept. 3	2	2	0	Do.
697	Sept. 5	Sept. 3	2	2	0	Do.
696	Sept. 6	Sept. 3	2	2	0	Do.
697	Sept. 6	Sept. 3	3	2	1	Do.
218	Sept. 14	Sept. 13	1	2	0	On ice.
218	Sept. 15	Sept. 13	2	2	0	Do.
218	Sept. 16	Sept. 13	2	2	0	Do.
688	Nov. 4	Nov. 3	1	4	1	In incubator.
696	Nov. 4	Nov. 3	1	4	0	Do.
697	Nov. 4	Nov. 3	1	4	0	Do.
	1910.	1910.				
730	Mar. 11	Nov. 9	2	2	2	On ice.
730	Mar. 29	Nov. 16	13	4	0	Do.

The following data, taken from above, give the place where the blood was kept, the length of time kept, the total number of cultures made, and the number which developed trypanosomes:

Blood kept on ice.

Time kept.	Culture tubes.	Positive cases.
1 day...	4	2
2 days...	9	3
3 days...	4	1
4 days...	2	1
5 days...	5	0
13 days...	4	0

Blood kept in laboratory.

Time kept.	Culture tubes.	Positive cases.
1 day.....	8	2
2 days....	12	0
3 days....	8	1
4 days....	8	0
5 days....	2	0

Blood kept in incubator.

Time kept.	Culture tubes.	Positive cases.
1 day.....	14	1
2 days....	2	0
3 days....	2	0
4 days....	4	0

Thus, eleven cultures developed trypanosomes, and the following shows the time required in each case for the organisms to appear in the tubes:

Blood on ice.

Time kept.		Time of appearance.	Remarks.
1 day....	a........	6 days.....	Good growth.
	b........	3 days.....	Do.
2 days...	a........	5 days.....	Do.
	b........	4 days.....	
	c........	6–4 days...	
3 days............		5 days.....	Poor growth.
4 days............		4 days.....	Moderate growth.
Mean.......		4½ days....	

Blood in laboratory.

Time kept.		Time of appearance.	Remarks.
1 day	a	3 days	Very poor growth.
	b	4-3 days	Very poor growth; moderate growth.
3 days			Not examined until 15th day, when it was positive.

Blood in incubator.

Time kept.	Time of appearance.	Remarks.
1 day	12 days	Very poor growth.

When the blood was kept in the ice chest at a temperature of about 16° C. for 1 to 5 days, only 7 out of 24 cultures developed, or 29 per cent. For blood kept in the laboratory the figure is 3 out of 38, or 8 per cent. With blood kept in the incubator, but one culture out of 22 produced trypanosomes. This shows that keeping the blood before the cultures are made has a destructive influence on the trypanosomes.

As to the time required for the trypanosomes to develop, the average is about 4½ days, yet tubes made from blood kept 4 days developed in 4 days. Furthermore, whereas when the blood was kept in the laboratory only 2 out of 8 tubes developed, the trypanosomes appeared on the third and fourth days. The implication here is that the greater part of the trypanosomes in the blood are either killed or so enfeebled that they are unable to develop, while the growth which takes place is due to the hardier survivors. This is supported by the character of the growth which was eventually brought about in the tubes. In no case was this luxuriant, and it was good in only three of the tubes, pointing to the conclusion that the number of trypanosomes present in the tubes was very much below the average.

In all of the cases considered above, control cultures made promptly after the blood was drawn were positive.

RESULTS OBTAINED WITH MEASURED QUANTITIES OF BLOOD.

The following table gives the results obtained with measured quantities of blood, the medium used being the laboratory make of beef bouillon, and the cultures being made the same day the blood was drawn. Unless otherwise stated, the culture tubes were kept in the room. In all cases given in the table where the quantity of blood was small, and the results negative, controls showed the blood used to contain trypanosomes.

Results obtained with measured quantities of blood.

Culture.	Date.	Cow.	Quantity of blood.	Result (+, positive; –, negative).	Time.
	1909		*c. c.*		*Days.*
4	Mar. 29	688	3.0	+	[1]6
5	do	688	1.5	–	(1)
31	Apr. 5	688	2.0	+	3
33	do	688	1.5	+	4
38	do	688	2.0	–	(1)
39	Apr. 7	688	2.5	+	3
41	do	688	2.0	+	3
42	do	688	1.5	–	(1)
43	do	688	3.0	+	4
53	Apr. 12	688	5.0	+	3
54	do	688	4.0	+	4
55	do	688	4.0	+	3
56	do	688	4.0	+	3
57	do	688	4.0	+	4
58	do	688	3.5	+	3
59	do	688	3.0	+	3
64	Apr. 24	695	2.0	+	4
65	do	695	1.5	+	....
66	do	695	.4	+	....
67	do	695	1.5	+	....
68	do	695	3.5	+	....
70	do	695	2.5	+	....
72	do	696	3.0	+	....
73	do	696	5.0	+	4
74	do	696	3.5	–	....
75	do	696	5.0	+	....
76	do	696	4.0	–	....
77	do	696	5.0	+	....
78	do	696	3.0	+	....
79	do	696	4.0	+	....
81	Apr. 26	697	2.5	+	4
82	do	697	2.0	+	....
83	do	697	2.0	+	....
85	do	697	1.0	+	....
86	do	697	2.5	+	....
87	do	697	2.5	+	....
88	do	697	1.0	+	....
89	do	697	.5	+	....
133	May 13	688	2.5	+	3
134	do	688	3.0	+	3
135	do	688	2.0	+	3
136	do	688	2.0	+	....
137	do	688	2.5	+	....
138	do	688	2.0	+	3
139	do	688	3.0	+	2
140	do	688	2.0	+	3
141	do	688	1.5	+	....
142	do	688	1.5	+	....
144	do	688	2.0	+	3
145	do	688	2.5	+	3
146	do	688	3.0	+	3
147	do	688	3.0	+	3
420	Nov. 17	218	1.0	–	....
421	do	218	2.0	–	....
422	do	218	3.0	–	....
423	do	218	4.0	–	....
424	do	218	5.0	–	....
425	do	218	6.0	+	6
426	do	218	7.0	–	....
427	do	218	8.0	+	6
428	do	218	9.0	+	6
429	do	218	10.0	+	6
436	do	218	1.0	–	....
438	do	218	3.0	–	....
440	do	218	5.0	+	....
441	do	218	6.0	–	....
442	do	218	7.0	+	....
443	do	218	8.0	–	....
444	do	218	9.0	–	....
445	do	218	10.0	+	5
	1910		*Drops.*[2]		
532	Apr. 7	697	1	–	....
533	do	697	2	–	....
550	Apr. 13	697	1	–	....
551	do	697	2	–	....
552	do	697	3	–	....
553	do	697	4	–	....

[1] Culture in incubator.

[2] 1 drop=0.0675 c. c.

Results obtained with measured quantities of blood—Continued.

Culture.	Date.	Cow.	Quantity of blood.	Result (+, positive; −, negative).	Time.
	1910		*Drops.*		*Days.*
574	Apr. 21	697	5	−	
575	do.	697	5	−	
576	do.	697	10	−	
577	do.	697	10	−	
618	July 14	697	5	+	6
			c. c.		
622	do.	697	1.0	+	
623	do.	697	1.0	+	
624	do.	697	1.0	+	
625	do.	697	1.0	+	

Here it is seen that the smallest quantity of blood to give a positive result was 5 drops, or 0.3375 c. c., and that this result was obtained only once out of three trials. Assuming 6,000,000 red cells and 10,000 leucocytes per cubic millimeter, we find as a possible proportion one trypanosome for 2,022,000,000 red cells and 3,370,000 whites. Hence to find the trypanosome in the circulating blood would be merely a piece of good fortune. Further, culture 444, containing 9 c. c. of blood, was negative, yet this amount of blood contains 90,000,000 leucocytes.

For the most part the bouillon used for the cultures was that made in the laboratory from beef, for ordinary bacteriological work. Some 16 tubes were used in which the medium was made from commercial meat extract. It was not treated with an alkali, and hence was acid in reaction. The growth in the latter medium was in general not so luxuriant as that in the laboratory make of bouillon, and in two cases the trypanosomes failed to appear at all, although controls (in laboratory bouillon) were positive.

Fourteen cultures were made in physiological salt solution, 6 parts per thousand. In one set of experiments with this medium 5 c. c. of salt solution was used in each tube, to which were added 2, 3, 4, and 5 c. c. of blood, respectively. Trypanosomes never developed, although in all cases the controls were positive. These results were at odds with those obtained by the Dudukalovs (see page 9).

In one set of tubes cow's milk was used, the results being negative.

GENERAL RESULTS OF CULTURAL WORK.

The results may be summarized as follows:

(1) *Trypanosoma americanum* grows readily in ordinary bouillon, made from either beef or mutton.

(2) The average time required for the trypanosomes to be readily detected in the tubes is 3½ days.

(3) The smallest quantity which gave positive results was 5 drops, or 0.3375 c. c. The largest measured quantity to give negative results was 9 c. c.

(4) There is a seasonal fluctuation, the trypanosomes being more abundant in the spring and summer than they are in the autumn.

OBSERVATIONS ON FRESH MATERIAL.

The successful cultures were those made by adding the blood of the cow to bouillon of several different kinds. The freshly made culture necessarily consisted of a red column, composed of an admixture of blood and the medium. Upon standing for about 24 hours the blood cells settled to the bottom of the tube, leaving above them a clear fluid composed partly of blood serum and partly of bouillon itself. At first the surface of this column was smooth and of a uniform red, but by the end of the second day it usually began to present appearances which were presumably caused by the rising to the surface of the leucocytes. These appearances, however, were very varied. In some cases the surface remained perfectly flat but showed itself studded with minute whitish specks and motes which, when large enough for their form to be determined, were of irregular contours and closely resembled particles of dust. Frequently, however, a fuzzy deposit appeared upon the surface, consisting of a reddish-white stringy mass, which might be elevated as much as 1 or 2 mm. These fuzzy masses never occupied more than a portion of the surface of the column of red cells. At other times this surface was differentiated into a series of ripples, representing in miniature the surface of wind-blown sand.

But in spite of these various aspects, there was never any difficulty in determining macroscopically (or preferably with the aid of a hand lens) whether the tubes did or did not contain trypanosomes, at least after they had had time, if present, to establish themselves. Frequently by the third day there could be distinguished on the surface of the red cells minute dots, differing from the motes above mentioned in that they were white and circular. When these had reached a certain size it could generally be seen that their top surfaces were not flat but convex, and when as sometimes happened they were supported by the masses of fuzz and thus carried above the surface they showed as more or less spherical bodies. At first these trypanosome colonies were very minute and frequently scattered over the surface in a more or less uniform manner, but as the culture got older they always became larger and often fewer in number. Increase in size is of course a matter of growth, and the diminution in numbers was doubtless a case of fusion of closely lying colonies. In mature cultures there were at times but two or three colonies—enormous white masses 2 or 3 mm. across.

The small colonies were always circular, the larger circular, oval, or irregular. A curved outline, however, was always maintained. The form of the colonies, however, is doubtless merely a matter of surface tension. Fusion of two very small circular colonies results in the production of a large circular one, but when a certain size is reached the surface tension is able only to impart to the compound colony a curved outline. It was at times to be noted that the separate units composing the large compound colonies were very incompletely fused.

Clearly, each separate colony which arose on the surface of the red cells in a tube represented a focus of infection, the later increase in bulk being merely due to the multiplicative activity of the trypanosomes. No accurate counts were made, but such foci probably ranged in numbers, in the various tubes, from half a dozen or less to perhaps 100. These foci of infection must in each case be either a single trypanosome, or some element not a trypanosome but which evolves into one, or two or more trypanosomes or such elements.

In the preliminary notice (Bulletin 119) it was stated that it was not possible to say what this was, that is, whether the element in the circulating blood of the cow was an actual trypanosome or something of an entirely different facies, and unfortunately such observations as have been made since do not settle this point absolutely, yet they leave little doubt resting upon it. Trypanosomes were never seen in fresh blood from the cow, but they finally were found in stained smears of centrifuged blood, the smears having been made 3 or 4 hours after the blood was drawn. It may be stated here that these organisms did not occur singly, but in clusters, and were evidently in a process of rapid multiplication. The probability that they arose from the division of a trypanosome, and not from something else, is so great as to be a practical certainty. The work of Wrublewski and Behn, previously quoted, supports this hypothesis. In that of the former, the trypanosomes described as parasites of the aurochs are so like *T. americanum* that the latter might be regarded as little more than a variety of the former. The failure to find the trypanosome in the perfectly fresh blood of American cattle is of little moment, since if the organism is only a variety of *T. wrublewski* it is in a strange host, and hence might be able to maintain itself in only very limited numbers. Moreover, it is a matter of common knowledge that trypanosomes may exist in the blood of animals in such small numbers as to evade observation with the microscope. A great many such cases have been brought out in the experimental work on the pathogenic trypanosomes of mammals, and it seems to be almost the rule for those of birds. Evidently, when a trypanosome can not be found in the blood with the microscope, it is more or less of a venture to claim that it exists there as a trypanosome and not as something else. Yet in the case of birds it is known that after failure to find them in the circulating blood they have been picked up in extremely small numbers in the bone marrow. Besides, in spite of the enormous amount of work which has been done on these flagellates, nothing has ever been discovered in the blood but an element instantly recognizable as a trypanosome.

Finally, there is Behn's discovery. But this trypanosome is very different from either *T. americanum* or *T. wrublewski*. It is not only a very much broader animal, but differs in that the nuclei are farther back in the body. It is quite possible, however, that this trypanosome, although the forerunner of the organisms found in the culture tubes by the German investigators, is a wholly different species from *T. americanum*. So far the cultural trypanosome of German cattle has neither been described nor figured, and it is hence impossible to compare it with that from American cattle.

ATTEMPTS TO DISCOVER THE TRYPANOSOME IN FRESHLY DRAWN BLOOD.

The experiments made at Washington to determine this point may now be given.

Freshly drawn blood from cattle was centrifuged, and preparations were thereby obtained in which the leucocytes were as abundant as the red cells. This work was done in June, July, and August, 1910, when the cultural method showed the trypanosomes to be abundant. Six different animals were used, of which four were healthy, one was in an advanced stage of tuberculosis, and one was suffering from a mild case of Texas fever.[1]

A large number of fresh preparations were examined, but nothing in the way of a trypanosome was ever found. In a search of this sort the examination of fresh material was then and still is believed to be the most efficient method, since the flagellate readily betrays its presence by its motility. The work was done with a 16 mm. objective and a No. 12 eyepiece, and a preparation containing as much blood as a large smear could be searched in a few minutes. A thorough test of this procedure led to the view that the trypanosomes could not be found in recently drawn blood, and the examination of stained smears was undertaken rather with the idea of looking for hypothetical "preflagellate" stages than for actual trypanosomes. Yet it was in these that the discovery was made. The trypanosomes were found on two slides, a small group in each case, out of some 25 examined.

Cultures were also centrifuged. The first experiment, made July 15, 1910, with a culture 23 to 24 hours old, revealed trypanosomes, singly or in clusters and either associated or not with white cells. Later experiments, made in August, reduced the time to 15 hours. Younger cultures were not tried.

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[1] This cow was tested in October.

The findings, however, were of considerable interest. In the 15-hour culture only a single trypanosome was found, but this was an organism having a body quite 20 microns in length, and a flagellum as long as the body, making it all of 40 microns long. The undulating membrane was short, and the appearance was typical for *Typanosoma americanum.*

In a culture 18½ hours old made from blood 5½ hours after it was drawn there were found several clusters of trypanosomes, one of which must have been composed of at least 75 individuals. Since in the culture tubes division of the flagellates is by no means a rapid process, requiring from 1 to 2 hours, multiplicative activity must have been going on for some time. At the slower rate, it would take 14 hours for one trypanosome to produce 64. The organisms found on the first day in centrifuged cultures differed in no respect, so far as could be determined, from those found in two and three day cultures, studied without centrifuging.

EVOLUTION OF THE TRYPANOSOMES IN CULTURE.

The history of the evolution of the trypanosomes, as it takes place in a successful culture, may now be traced.

As already stated, there is a certain variability in the rate of evolution, but it may conveniently be considered under three headings—the period of growth, of culmination, and of decline—although the three processes to a certain extent overlap.

In cultures 2 to 3 days old there are present a small number of organisms, say from 1 to 6 to each preparation, a preparation probably containing 1 cubic millimeter of the culture. The animals are ordinarily short and relatively broad, with the anterior half broader than the posterior. At times, however, they are quite slender. A flagellum is always present and in most cases a short undulating membrane can easily be seen. The cytoplasm is hyaline. With ordinary light, granules can not as a rule be seen, but dark-field illumination shows them to be present. It may also here be noted that this method revealed the fact that in the adult trypanosomes the flagella often show a double contour, even to the extreme tip. The organisms are either solitary, in pairs, or in clusters. The clusters are nearly always of few individuals, but this of course depends upon the rate with which multiplicative activity has been inaugurated. The flagellum and undulating membrane are in constant action, and progression in a slow, unsteady manner, with numerous changes of direction, is frequent.

Cultures 3 to 4 days old show all of the phenomena presented by the earlier cultures. There are very many more trypanosomes present, however, and the clusters average much larger. Solitary forms are relatively much rarer, almost all of the animals being in the clusters. The trypanosomes themselves have become longer. The flagella and undulating membranes are in constant motion, and it may here be stated that motility does not seem to fluctuate with age, senile and youthful forms showing it in approximately the same degree.

Evolution now follows the lines already indicated. In the 4 and 5 day cultures solitary forms occur, but are scarce. Nearly all the trypanosomes present are in clusters, which may consist of 3 to 4 individuals, or be of enormous size. One, from a 4-day tube, measured 156 by 190 microns, and must have been composed of thousands of trypanosomes. The individual animals are larger; some long and slender, or crithidia-like; others show a typical trypanosome contour, while still others have become club-shaped. Large, stout divisional forms are frequent. In many the cytoplasm has become very granular.

From the fifth and sixth days onward the cultures begin to present a far more diversified appearance. There are present large and small clusters in which the trypanosomes may be band-shaped or club-shaped. There are many more free individuals, doubtless those which have become separated from the clusters. The free forms are band-shaped, club-shaped, or short oval bodies. Any and all of these may be in division. There also appear in the older cultures very large bodies with two or more flagella, no doubt resulting from a more or less abnormal division process. The club-shaped forms and the giant trypanosomes are marks of degeneracy, and as the culture ages more and more of the trypanosomes begin to undergo senile decay, and the culture eventually dies out.

No accurate data were kept as to how long the cultures generally lasted, but by the end of a month they are very evidently degenerate. In one case a tube charged 63 days previously was observed to show, microscopically, a large number of apparent colonies. A study of these colonies under the microscope showed, however, that they consisted merely of great masses of granular balls, with here and there a feebly motile, misshapen, and intensely granular trypanosome.

The process of evolution of the individual, or of evolution combined with so-called involution, is not, except at the outset, difficult to follow. As given above, a solitary trypanosome having a total length of 40 microns was found in a centrifuged culture 15 hours old. (In the 2 and 3 day cultures the trypanosomes are not so large as this.) It will probably not be far from the mark to look upon a trypanosome of this size as the originator of the clusters which appear in the tubes. Division is always by longitudinal splitting, but may be equal or unequal. The observations rather favor the view that it is at first unequal, the original mother cell giving off a short, relatively broad bud. Such unequal divisions were seen in the ordinary (not centrifuged) cultures, and were not uncommon in one of the centrifuged cultures of the first day. At all events, beginning the series with a short, broad, flagellated element, the history is as follows: This element divides, and the two daughter cells are also at first short, broad organisms provided with flagella and undulating membranes. The cytoplasm is hyaline, and fine granules are probably always present. An increase in length produces a relatively more slender form, which, in its turn, becomes a band-shaped typical trypanosome. In time, the anterior half becomes broader and rounded, like the head of a club, the posterior half remaining narrow. The flagellum extends forward from the anterior tip of the broad anterior half and carries with it a narrow band of cytoplasm, which is probably composed partly of endosarc, since it is frequently granular. The narrow posterior end becomes narrower; it is reduced to a mere spike, and finally disappears, leaving the monadine forms which show a flagellum either extending free or accompanied for a part of its length by a band of cytoplasm. In certainly a great many cases, however, and perhaps all, before the complete atrophy of the posterior end, the head of the club had undergone a distortion which carries the point of origin of the flagellum around to one side of the body, so that forms are obtained wherein the flagellum extends out at right angles to the longitudinal axis of the body.

Along with the morphological changes there is a conspicuous change in the granularity of the cytoplasm. In the young trypanosomes the granules are small, but there is a gradual increase in size and numbers, and the senile forms are closely packed with coarse granules. The monadine form degenerates into a coarsely granular ball.

The genesis of the colonies takes place as follows: A cluster is started, probably by a single trypanosome. This, by division, produces a pair, joined by their posterior ends. A second division produces a group of four, but the arrangement is not radial, but linear. The four are united, in common, by their posterior ends, but one of the pairs is slightly in advance of the other. In further divisions this linear arrangement is maintained, so that the clusters do not consist of rosettes, but of strings. Since, however, any given pair of trypanosomes is very nearly at the same level as the pair next to it, the linear disposition is more or less completely masked, and rounded clusters are produced. The actual arrangement may, however, be nicely demonstrated by observing a rounded cluster by dark-field illumination. As the cluster becomes heated by the rays it spreads out, becoming larger and looser, and then it can be easily seen that such a cluster consists of a number of closely related strings of trypanosomes. It may also be seen when trypanosomes have multiplied in a sealed preparation on a slide. Here, if the blood film be sufficiently thin, the groups are constrained to develop within one plane, and the linear arrangement is often very plain. Accordingly, the rounded cluster is a group of the second order, made up by the strings, which are in their turn made up of individual trypanosomes. Occasionally such strings (or perhaps a better term is bouquets) of trypanosomes were seen which were bipolar; that is, there were two strings extending from a central point in opposite directions. The strings may possibly also give off lateral branches.

In view of the organization of the clusters, as just indicated, there is no objection to the view that each has arisen from a single trypanosome. If this be so, we should get, as a very rough average, say 25 to 50 trypanosomes per culture tube, or perhaps 10 per cubic centimeter of blood. This gives one trypanosome to 1,000,000 white cells. The data given on page 20 show, however, that the trypanosomes are not so abundant as this. Such figures are little more than guesses, however, although they show that the trypanosomes are very rare in the circulating blood of the cow.

It may be of interest to give certain of the observations in detail: Fresh preparations from culture tubes 2 to 3 days old, examined under the microscope, show in abundance clumps composed partly of red cells and partly of leucocytes. These clumps stand out quite sharply from the film of red cells and evidently possess a considerable degree of consistency. Their production is probably in part due to the fact that as the leucocytes rise to the surface they tend to entangle a certain number of red cells; but there seems to be some other influence at work, because at times these clumps consisted entirely of red cells, and the red cells were always in the majority. In all cases the red cells, as a result of mutual pressure, were more or less misshapen.

It was very quickly learned that the place to look for the first trypanosomes was in these clumps. In the early cultures one or two trypanosomes could usually be found in association with one of them, either in the midst of the blood cells or lying at the periphery, in the narrow clear space which usually separated a clump from the surrounding film of erythrocytes. A day later there might be a considerable number of trypanosomes in such a situation, mostly in little clusters around the edges of the clump. In a number of cases, where preparations were obtained showing trypanosomes in association with the clumps, the position of these was determined by means of the mechanical stage, and the preparation was set aside. Examinations on the following day always showed a conspicuous increase in the number of trypanosomes, and it was in such cases as these that the growth of the trypanosomes in strings or bouquets was at times demonstrated.

The appearance of trypanosomes in association with these clumps of blood cells suggested at once that it was here that the origin of the foci of infection was to be found, and, since the clumps were small, that the problem of whether it was an actual trypanosome or some resting stage which gave birth to the trypanosomes in the cultures could easily be solved. In the endeavor to elucidate this point the dark-field illumination was at first used and some very deceptive appearances were noted.

As stated above, these clumps are composed largely or wholly of red cells, the peripheries of which, with dark-field illumination, show as bright bands of a quite appreciable width, inclosing a space which does not reflect the light and is accordingly clear. Since the cells are closely packed together, the appearance is that of a region marked out with very irregular polygons. When the preparations studied were from cultures in an appropriate stage of development, that is, when the trypanosomes were still scarce, observation would at times appear to show the edges of one of these red cells to be in motion. This motion at once recalled that of the flagellum of a trypanosome, as it indeed proved to be, for presently it could be seen that it was not the edge of the red cell that was in motion, but a thread, a flagellum, and by careful observation the flagellum could be traced to a faintly appearing trypanosome. The curious point about this phenomenon was, however, that although a point might be selected where the most careful scrutiny failed to reveal the presence of a trypanosome, the serpentine movement would presently manifest itself, and then the trypanosome itself could be discerned. It was as if the animals sprang into being full fledged.

The mystery was solved by a study of the clumps by transmitted light. It is probably a matter of common experience that fresh preparations are not very satisfactorily observed with an oil-immersion lens with daylight. The usual method was then somewhat modified. The small arc lamp belonging to the dark-field apparatus was used, its light being first passed through a piece of "euphos" glass, and then through a vessel containing a solution of methylene blue. Euphos glass cuts out the destructive ultra-violet rays; the methylene-blue solution is for the benefit of the observer's eyes, and can be made of whatever density desired. Finally—and this is of importance—immersion oil must be placed between the top of the condenser and the slide. This procedure permits the use of the highest-power eyepieces with a 2 mm. apochromatic lens, and the trypanosomes may be studied under powers of 1,500 to 2,250 diameters.

It was by this means learned that the trypanosomes which appeared so mysteriously were already present in the mass of red-blood cells, and had merely shifted their position. But, unfortunately, no light was shed on their origin. In a great many cases round cells, the appearance of which was not wholly that of normal leucocytes, were individually kept under observation for several hours, but nothing was ever seen to take place. The first trypanosomes ever seen in preparations from any culture were elongated, flagellated organisms.

In the early cultures the trypanosomes occurred either singly or in groups of two or three. As has already been pointed out, the pairs arise by division, but there is another way whereby paired animals and clusters of very few might take origin. This would be by agglutination. Besides being associated with the clump of red and white cells, the trypanosomes are found wandering through the preparation. They create little or no disturbance amongst the red cells, since they travel at a slightly higher level and may indeed be creeping on the under surface of the cover glass. Their movements are slow and unsteady and changes of direction are frequent. The following detailed observations are typical of what may be seen:

MOVEMENTS OF TRYPANOSOMES IN CULTURES.

In a culture two days old, studied March 5, 1910, two young trypanosomes came together at 4 p. m., and for 55 minutes what was seen can best be designated as a wrestling match between the two. Movements of the flagella and undulating membranes were practically continuous, and the two kept their bodies constantly curved, each looped around the other. At 4.55 they both straightened out and lay side by side, bodies in contact, the flagella pointing in the same direction: This position was, however, maintained but for a minute or two, after which they again bent their bodies, looped themselves together, and resumed the apparent struggle. At 5.30 the observation was interrupted, to be resumed at 7.15 p. m., when the same condition of affairs was found.

In another case, in a 3-day culture, two slightly more mature flagellates were seen to come into contact and to remain so for several hours. Here, as in the case described above, the flagella and undulating membranes were in constant movement, and the animals also spent a part of the time each looped around the other. But, in addition, they would frequently partly separate and then each, with straight longitudinal axis, appose its body to that of the other. When so disposed, they were oriented indifferently in the same or opposite directions, and sometimes the end of one was opposite the middle of the body of the other. Under such circumstances it was generally quite impossible, even with the very favorable conditions under which the observations were made, to trace any line of demarcation between the two; but neither here nor in any other of the cases observed was there any reason to suspect conjugation. Neither is it believed that unions of this sort were permanent, since contact between the two was never by any specified portion of the body, and might be instantaneously broken, whereas the pairs arising by division remained attached, and always by their posterior ends.

When the trypanosomes were not rare in the mount, it was not at all unusual for a solitary individual to leave the edges of the cell clumps and wander alone in the preparation. There might be quite a few trypanosomes wandering through the preparation, but there was never any evidence of any influence exerted at a distance. But in a number of cases it was noted that as soon as two individuals came into contact each at once became more energetic.

THE PROCESS OF MULTIPLICATION.

The actual process of multiplication was not seen many times, but the following observation probably epitomizes the process:

In a 4-day culture, at 2 p. m., March 7, 1910, there were found a large and a small trypanosome in contact. The former was a wholly normal animal of adult aspect, the latter egg-shaped but with a pointed posterior end and a short flagellum. It was rather less than half as long as the adult animal, and lay in contact with the anterior half of it. In a very few minutes it was seen that the flagellum of the egg-shaped element was much longer, and a little later the element itself was seen to be split halfway from the anterior to the posterior end. Unless the appearance of singleness of this body when first seen was deceptive, and due to the angle from which it was observed, the division into a partly separated element, with the two anterior ends each provided with a flagellum, did not require more than 15 or 20 minutes.

At 2.35 p. m. the large trypanosome broke away from the paired element, but some 10 minutes later joined it again, wrapping its body around the pair in such a way that there was obtained an oval body provided with three flagella at one end. The trio remained in intimate contact until 4.30 p. m., and during all of this time it was possible only momentarily to see any line of demarcation between the three elements composing it. At 4.30 the large trypanosome again separated from the pair, and then it was possible to see that although the two small cells were still in contact by their posterior ends, they had increased very considerably in length, and were now much like the young forms seen in the young cultures.

When the original pair was first seen it was taken to be a case of unequal division, but the subsequent behavior of the large trypanosome is rather against such an interpretation. The little trypanosomes, in which the body is oval, and may or may not be pointed at the ends, were frequently found, either singly or paired, in the clusters occurring in the young cultures, and other cases of division like that above described were at times seen. In these, so far as the observations go, the pairs arising from division remained in contact, but it is not impossible that separation may sometimes take place before growth is completed, thus giving rise to solitary oval forms. It is also theoretically possible that they arise from unequal division, as in *Trypanosoma lewisi*, but unfortunately neither my preserved material nor my observations on fresh material enable me to settle this point.

Besides the oval form, there was occasionally found in the early cultures a round element, about as large as a red blood cell, provided with a long flagellum. Such are presumably to be regarded as modifications of the oval form.

MOTILITY OF THE TRYPANOSOMES.

Attention has been called to the almost constant motility of the trypanosomes. This was, however, subject to a certain variability, although it was not possible to determine upon what factors this variability depended. The normal movement was an undulation of the flagellum and undulating membrane, accompanied by a certain amount of flexion and torsion of the anterior part of the body. The younger trypanosomes were frequently seen to have their bodies bent into circles, simultaneously displaying energetic movements of the flagella and undulating membranes. Such positions might be maintained as long as the observation lasted. But in the fully fledged parasites the longitudinal axis was usually straight and the postnuclear part of the body rigid.

At times trypanosomes, entangled amongst blood cells or granular débris, acted as though seeking to get free. In such cases periods of violent activity, during which the movements lacked all regularity, alternated with periods of complete rest. In the cases noted above, where two trypanosomes kept in company for considerable periods, the movements also lacked regularity.

On one or two occasions, when the temperature of the laboratory during the night had been unusually low, the trypanosomes observed in the morning seemed rather sluggish. This observation suggested the following experiment: A tube was placed in a vessel containing ice and salt, and kept at a temperature of just above freezing for nearly two hours. A preparation was then brought under the microscope as quickly as possible, and immediately examined, with the result that the trypanosomes were found to be displaying an activity fully up to normal.

Nor is it certain that heat increases motility. Trypanosomes always become much more active with dark-field illumination, but this may be laid to the ultra-violet or Roentgen rays rather than the heat.

OBSERVATIONS ON FIXED MATERIAL.

The observations made on fixed material confirm and supplement those made on fresh preparations. In one respect, moreover, they carry the study somewhat further, since in two cases smears made from fresh blood show trypanosomes (figs. 1 and 2).

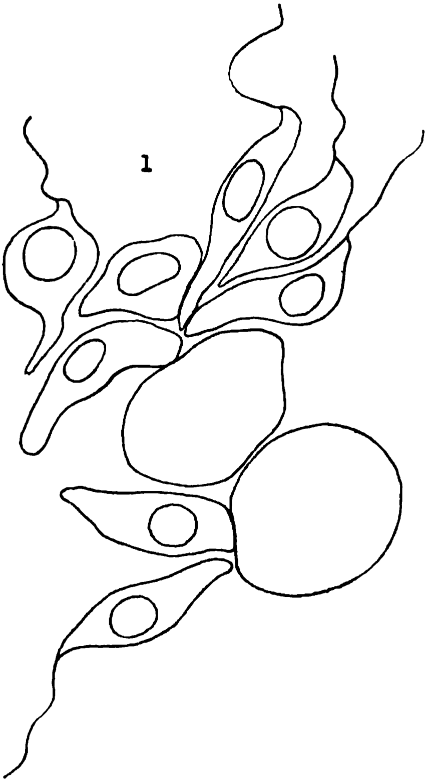

FIG. 1.—Forms of *Trypanosoma americanum* from centrifuged blood.

The blood from which these smears were made was drawn at the Bureau Experiment Station, sent into the laboratory, and centrifuged before the preparations were made from it. The interval was probably about four hours. Hence the blood was not in a strict sense freshly drawn, yet the observation compares with many others made upon trypanosomes. In many cases in the literature where trypanosomes are described as present in the circulating blood, the blood in which they were found had either been removed from the living animal for some time or had even been taken from a dead animal. There had therefore been time for it to cool to the temperature of the air. A case in point is that of *Trypanosoma wrublewski*, found only in blood from dead bison. But in the case in hand it is believed that the removal of the trypanosomes from the circulation had an immediate effect, for the parasites, as seen in figures 1 and 2, are evidently in rapid division. Their extreme scarcity in the cow is practical proof that in such a situation the multiplicative energy is in abeyance.

The only stimuli to which the parasites in the drawn blood were subjected were the lowering of the temperature, the defibrinating of the blood, and the mechanical disturbance consequent upon centrifuging. It is hardly likely that defibrinating could have any effect, and the centrifuging was carried on for only a few minutes, the preparations being then made at once. Hence no time was given for the number of divisions which the figures show to have taken place. Probably, then, it is the lowering of the temperature which induces multiplication, although it does not necessarily follow that this is in any way correlated with the removal of the trypanosomes by a biting fly. The mere cooling itself might readily furnish all the stimulus needed.

MORPHOLOGY OF THE FORMS IN THE BLOOD.

Taking up now the trypanosomes as they appeared in the centrifuged blood, it will be seen that they are normal in shape, flagellated, and possess a large trophonucleus and a conspicuous vacuole. Unfortunately, the stain used on the two slides on which they occurred was not in proper condition, and stained the cytoplasm so intensely that the situation of the kinetonuclei was obscured.[1]

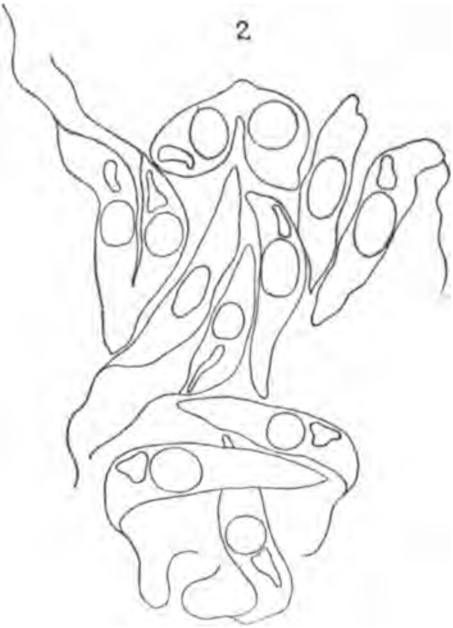

FIG. 2.—Forms of *Trypanosoma Americanum* from centrifuged blood.

For the group shown in figure 1 the average size of the body was 14.7 by 4 microns. In the case of figure 2 the dimensions were: Forms in division, 13.9 by 4 microns; forms not in division, 16.8 by 3.6 microns.

A selection of 14 of the figured flagellates, confined to those which did not appear to have been greatly distorted in fixation, gave an average measurement of 16.8 by 3.8 microns. Newly born daughter cells can not be larger and are probably somewhat smaller than the mother cells from which they were derived. Hence the trypanosome, as it would appear in the circulating blood, probably has a length of at least 20 microns excluding the flagellum, and, as noted on page 24, a trypanosome of this size was found in a culture of the first day.

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[1] Efforts to improve the staining of these two slides were futile. The stain resisted a treatment with acid alcohol of sufficient duration to injure the trypanosomes themselves.

MORPHOLOGY OF THE FORMS IN CULTURE.

Figures 3, 4, 5, and 6 show the appearance in smears from the early cultures. The shape is to a large extent artificial; for one thing, the early stages appear to contract on drying, becoming shorter and broader. Primarily, however, the distortion is due to the fact that as the spherical cluster dries it is fixed flat, with results such as are shown very plainly in figure 5. The two cells shown in figure 4 are probably somewhat contracted. In the film they measured 10 microns long. In figure 6 the largest trypanosome has the body 24.7 microns long. The group of six, shown in this figure, give clear indications of the method of their origin, and are probably all derived from a single trypanosome. All but one are oriented in the same direction, and it is evident that this odd member of the group has just been forced out of the place which it had been occupying.

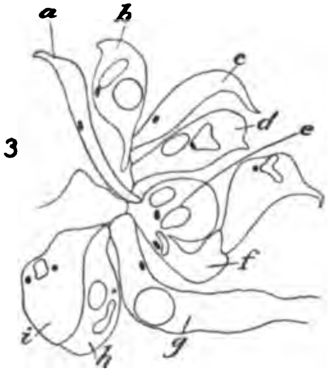


FIG. 3.—Forms of *Trypanosoma americanum* from bouillon culture 96 hours old. The individual members of the cluster are distinguished by the letters *a* to *i*.

Evolution, as already set forth on pages 24 et seq., results in the production of longer and relatively and often actually more slender flagellates. Figure 7 from a culture on the fifth day shows two trypanosomes. They are longer and somewhat more slender than those shown in figures 1 and 2. Figures 8 and 9 are from cultures of the same age. Here the animals are long and slender, that of figure 8 measuring 27.8 microns for the body. The undulating membrane also shows more distinctly in this figure. It was such forms as these which were spoken of as crithidial in the preliminary notice, but so much confusion exists in the literature as to what precisely are the characters of the genus *Crithidia* that the derived adjective is perhaps best let alone.

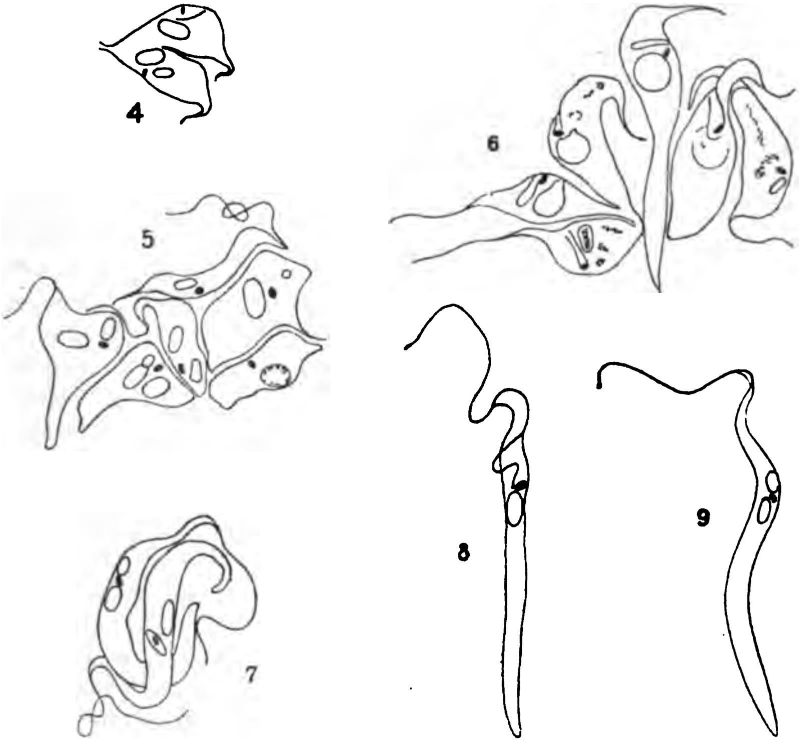
Figures 11 to 15 show forms from older cultures. Evidently after a certain maximum length is reached the animals again become broader. Finally, by a considerable thickening of the anterior end, the club-shaped form is produced. Very marked, also, is the increased conspicuousness of the undulating membrane.

In figures 13 and 14 are shown, among others, forms having a broad, rounded anterior end. Posteriorly the body is rigid and tongue-shaped, and this portion finally degenerates and disappears. Anteriorly the cytoplasm extends out in a long tapering portion, very flexible and mobile in the living animal and bearing the undulating membrane. This portion also becomes absorbed in the genesis of the monadine forms, and trypanosomes having this outline are doubtless more or less senile.

Figure 12 shows the largest individual found in the preparations, the body alone measuring 38 microns.

CYTOLOGY OF THE FORMS IN CULTURE.

Along with the changes in size and shape there are conspicuous cytological changes. With reference to these, however, it is desirable to say that the material used was all "dry," and all stained with Wright's stain. Of late a good deal of the work on trypanosomes has been done with material fixed by the "wet" method, and the dry method has been extensively criticized. But the use of Wright's stain on dried blood is a standard procedure, and the results are so evidently accurate for such delicate structures as leucocytes that they can scarcely be very far wrong for trypanosomes.



FIGS. 4 to 9.—Forms of *Trypanosoma americanum* from bouillon cultures 112 hours old.

In the trypanosomes from the centrifuged blood of the cow the flagella stained, but poorly. In the early cultures, 2, 3, and 4 days, they stain, but often very faintly, this peculiarity being the cause of the error made in the preliminary notice. Later, however, their affinity for the stain becomes much greater, and in the fully fledged animals the flagella are conspicuous. The color is always red. In nearly all cases the tip is thickened to form a minute knob, as in *Trypanosoma wrublewski*. In the newly born forms the flagellum is short; in the adults it is long; probably on the average it is as long as the body. Frequently, however, in the older cultures, the flagellum is two or even three times longer than the body.

In fresh preparations an undulating membrane is always in evidence, but in stained material made from young cultures it can not as a rule be made out. Later it broadens and becomes conspicuous, but is always short.

The kinetonucleus from the first to the last stains intensely, usually a deep garnet color. It is sometimes round, more usually oval, and appears merely to constrict into two at the time of division. It seems always to be associated with a vacuole, which is at times as large as the trophonucleus. In cultures 2, 3, and 4 days old, when the trypanosomes are in rapid division, this vacuole is obviously merely a cavity within the cytoplasm. It is of irregular outlines, sometimes lobulated, sometimes almost tubular. It presents the peculiarity that in these early stages of evolution it appears to be open to the exterior. The appearance presented recalls what is found in *Euglena*. Some euglenoid type might easily have been the ancestor of the Trypanosomidæ, in which case this vacuole might be regarded as the rudiment of a cytopharynx. The data presented, however, are obviously insufficient to warrant doing more than putting forward the above as a possible suggestion.

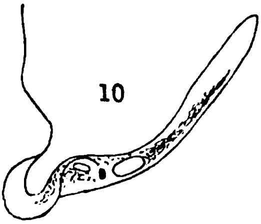
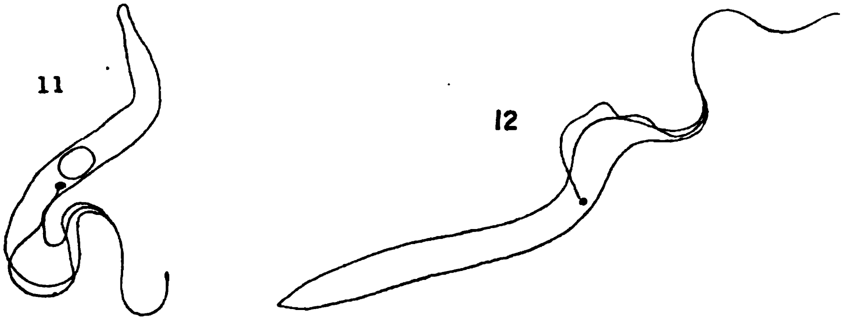


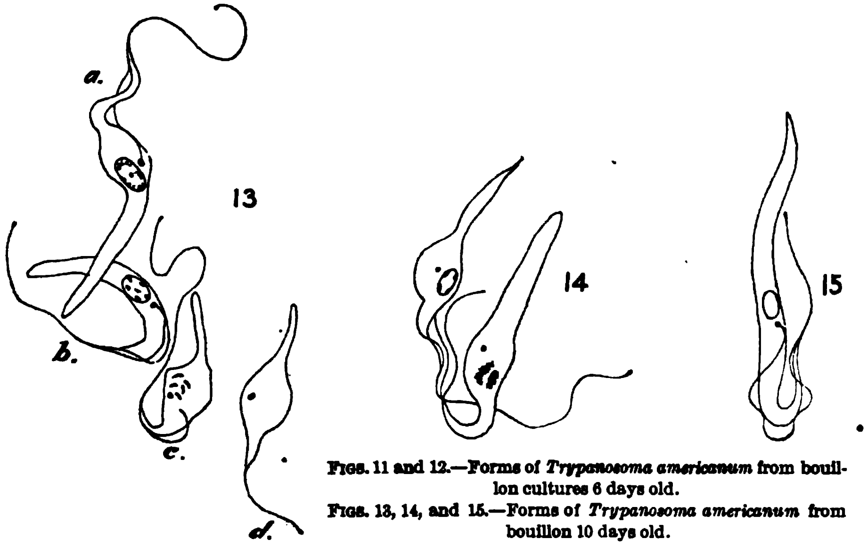
FIG. 10.—*Trypanosoma americanum* from bouillon culture 3 days old.

Later, the vacuole becomes round or oval, ceases to give the appearance of being connected with the exterior, and furthermore absorbs the stain, becoming pink. Although in adult trypanosomes it frequently can not be demonstrated, it is perhaps a constant feature and has been found in the monadine forms, the end terms of the series.

As well as could be made out in the trypanosomes from the freshly drawn blood, the trophonucleus consisted of a large, tense sac, and such is clearly its condition in animals from the young cultures. It stains homogeneously and so faintly that the actual color is often difficult to determine; generally is of a reddish cast. In the very early cultures—2 and 3 days—the trophonucleus is very conspicuous, contrasting sharply with the blue cytoplasm. Later it becomes less homogeneous, presenting a ground substance in which is a quantity of amorphous matter having a different staining reaction.

In the late stages the appearance is that of the conventional trypanosome nucleus, an oval body provided with a number of large, rounded granules. The appearances, however, are manifold, and have not been worked out in detail. Presumably, two factors are at work—the age of the trypanosome and its state with reference to division—and each of these is superposed upon the other.





FIGS. 11 and 12.—Forms of *Trypanosoma americanum* from bouillon cultures 6 days old.
FIGS. 13, 14, and 15.—Forms of *Trypanosoma americanum* from bouillon 10 days old.

The cytoplasm in the early stages stains solidly, but is denser in the middle of the body than at the ends. It is always a clear blue. For the first several days it appears to be provided with a considerable number of small vacuoles of uniform size. Since, however, observations on fresh material show these young trypanosomes to contain granules, and since there is no differentiation of the cytoplasm in the fixed preparations other than these apparent vacuoles, the probability is that they are really granules which refuse the stain. This supposition receives support from the fact that the granules of leucocytes at times appear as holes in the stained material. Later, the cytoplasm loses its solidity and homogeneity and conspicuous blue and violet granules become abundant, and in old cultures the trypanosomes frequently consist of little else than sacs more or less completely filled with coarse granules.

PRINCIPAL CHARACTERISTICS OF TRYPANOSOMA AMERICANUM.

Trypanosoma americanum is a large trypanosome. Figure 12 shows the largest specimen found, the body measuring some 38 microns in length. In this particular case the flagellum was either short or else failed to stain throughout. But since the flagellum is normally as long as the body, a total length of 75 microns is by no means unlikely.

The most marked peculiarity, however, is the very short undulating membrane. The kinetonucleus may be in front of, alongside, or behind the trophonucleus, and the two are always close together. But the reason for the shortness of the undulating membrane is that the nuclear system is pushed forward. The usual situation for the trophonucleus of a trypanosome is near the middle of the body, but in *T. americanum* it is at the junction of the anterior and middle thirds. That is, the distance from the middle part of the trophonucleus to the anterior end of the trypanosome averages 33 per cent of the body length, and in the specimens measured ranged from 25 to 40 per cent. In this respect *T. americanum* differs from the *T. transvaliense* phase of *T. theileri*, in which, according to the data given by Luhs, this distance is about 50 per cent of the whole. Here again it agrees with *T. wrublewski*, although even in the latter the nucleus, according to the published figures, is hardly so far forward.

CONCLUSIONS.

1. *Trypanosoma americanum* lives, in all probability as a typical trypanosome, in the blood of perhaps 75 per cent of yearling and adult American cattle, but is not present in young calves.
2. It comes very close to *T. wrublewski* of the European bison, and may be only a variety of that species.
3. Removal from the circulating blood stimulates multiplicative energy, apparently merely as the result of a cooler environment.
4. Removed from the cow and placed under appropriate conditions, multiplicative energy runs far in advance of growth energy; hence—
5. The trypanosomes divide and redivide very rapidly, and in consequence become smaller than the blood forms.
6. At the end of a few days, multiplicative energy weakening, the organisms have an opportunity to grow and to reach their normal size.
7. The adults are at first very slender, but in time increase in breadth and may become very large.

8. As the cultures reach and pass their maxima the individuals become club-shaped and eventually transform into rounded or oval elements, provided each with a long flagellum.

9. Changes in the morphology of the nuclear system, and in the texture and chemical nature or composition of the cytoplasm, accompany changes in the facies of the entire organism.

10. A distinguishing character is the situation of the trophonucleus, which is normally at the union of the anterior and middle thirds.

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A. D. MELVIN, CHIEF OF BUREAU.

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VARIETIES OF CHEESE:

DESCRIPTIONS AND ANALYSES.

BY

C. F. DOANE, M. S.,
Assistant Dairyman, Dairy Division,

AND

H. W. LAWSON, M. S., M. D.,
Office of Experiment Stations, Department of Agriculture.

[A revision of Bureau of Animal Industry Bulletin 105.]

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., August 31, 1911.

Sir: In 1908 there was published as Bulletin 105 of this bureau a paper entitled "Varieties of Cheese: Descriptions and Analyses," by Mr. C. F. Doane, of the dairy division of this bureau, and Dr. H. W. Lawson, of the Office of Experiment Stations of this department. As the supply of that bulletin is exhausted, and as it has been found desirable to make a few additions and some slight revisions, I have the honor to transmit herewith the copy for a revised edition and to recommend that it be issued as a new bulletin. A few new varieties have been added and certain descriptions in the first edition have been revised to conform to present usage.

As was stated in transmitting the original manuscript, the work is a compilation of descriptions and analyses of all the varieties of domestic and foreign cheese about which it has been possible to obtain such information in the literature bearing upon the subject. In a number of cases only meager details could be secured, and owing to the size of the work the descriptions are necessarily of a very condensed nature.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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VARIETIES OF CHEESE: DESCRIPTIONS AND ANALYSES.

INTRODUCTION.

The amount of cheese imported into the United States is increasing rapidly. During the six years from 1900 to 1905, inclusive, the value of the imports increased from $1,946,033 to $3,875,161. Italy and Switzerland supplied the bulk of this cheese, most of the remainder coming from France and Holland. The best known of the varieties of cheese imported were the Parmesan and Gorgonzola from Italy, the Emmental from Switzerland, the Roquefort, Camembert and Brie from France, and the Edam from Holland. The growing demand for cheese is not, however, confined to these well-known varieties, much interest being manifested in many kinds as yet of very little commercial importance but highly esteemed in the localities where produced.

Attempts have long been made in this country to imitate some of the European varieties, and in some instances the results have been decidedly successful. The manufacture of Swiss, or Emmental, and of Limburg types has become well established. The investigations conducted at the Storrs Agricultural Experiment Station in Connecticut have shown that cheese of the Camembert type, equal in every way to the imported article, may be produced in the United States. This department is cooperating in investigations of this kind, and recently results have been obtained which make it practically certain that a cheese of the nature of Roquefort or Stilton can likewise be produced in this country.

Information concerning the manufacture and composition of the numerous varieties of cheese is not very accessible to English readers and the apparent need of some work of reference, in connection at least with the importation and home production of cheese, has therefore led to the preparation of the descriptive notes and the compilation of the analytical data contained in this bulletin.

The descriptions are for the most part based upon data contained in treatises on dairying and in articles in foreign periodicals. While in many instances they are very incomplete and possibly at times inaccurate, they nevertheless contain in condensed form practically all the important information that it has been possible to secure in an extended search through the literature relating in any way to the subject. Owing to the large number of publications consulted, it has seemed impracticable to give references to the descriptive matter.

The analyses have been compiled in most instances from the original publications. In all cases, however, the sources of the data have been given in the list of references which follows the table of analyses. No effort has been made to collect the numerous analyses of filled cheese, and in the case of American Cheddar cheese only a part of the available data has been included in the compilation.

DESCRIPTIONS OF VARIETIES OF CHEESE.

ABERTAM.

This is a hard rennet cheese made from sheep's milk in the region of Carlsbad, Bohemia.

ALEMTEJO.

This name is applied to rather soft cheeses made in the Province of Alemtejo, Portugal. They are cylindrical in shape and are made in three sizes. averaging in weight about 2 ounces, 1 pound, and 4 pounds, respectively. They are made for the most part from the milk of sheep, though goat's milk is often added, especially for the smaller sizes. The milk is warmed and curdled usually with an extract prepared from the flowers of a kind of thistle. The cheeses are ripened for several weeks.

ALPIN.

This is a kind of Mont d'Or cheese made in the Alpine regions of France. It is also known as Clérimbert. The milk is coagulated with rennet at 80° F. in 2 hours. The curd is dipped into molds 3 to 4 inches in diameter and 2½ inches in height. The cheese is allowed to drain and is turned several times during one day, after which it is salted and ripened for 8 to 15 days.

ALTENBURG.

This is a goat's-milk cheese made in Germany, where it is known as Altenburger Ziegenkäse. A cheese is 8 inches in diameter, 1 to 2 inches in thickness, and weighs about 2 pounds.

AMBERT.

This cheese, known as Fourme d'Ambert, is a cylindrical-shaped imitation Roquefort cheese made from cow's milk. It is said to differ from other forms of blue or imitation Roquefort cheese made in the southeastern part of France in that the salt is mixed with the curd rather than rubbed on the surface of the cheese.

ANCIEN IMPERIAL.

The curd is prepared in the same manner for this cheese as for Neufchâtel. The cheese is about 2 inches square and one-half inch thick. It is also known as Petit Carré and when ripened as Carré Affiné. The cheese is sold and consumed both while fresh and after ripening. The ripening process is not essentially different from that of Neufchâtel.

APPENZELL.

This cheese, which is very similar to Emmental, is made in the Canton of Appenzell, Switzerland, and also in Bavaria and Baden. It is usually made of skim milk, but sometimes of whole milk.

BACKSTEIN.

Backstein, meaning brick, is so called from its shape, but it is not identical with the Brick cheese made in the United States. The process of manufacture is similar to that of Limburg.

BANBURY.

This was a soft, rich cheese, very popular in England in the early part of the nineteenth century. It was a cylindrical cheese about 1 inch thick.

BARBEREY.

This is a soft rennet cheese resembling Camembert and deriving its name from the village of Barberey, near Troyes, France. It is also commonly known as Fromage de Troyes. The milk while still fresh and warm is coagulated with rennet, the time allowed being usually about 4 hours. The uncut curd is put into a wooden mold having a perforated bottom. After draining for 3 hours the cheese is turned into an earthenware mold, the wooden one being removed after 24 hours. The cheeses are salted, dried in a well-ventilated room, and ripened for about 3 weeks, usually in a subterranean curing room. In summer the cheese is often sold without ripening. A cheese is 5 to 6 inches in diameter and 1½ inches in thickness.

BATTLEMAT.

This is an Emmental cheese made in the Canton of Tessin, Switzerland, in the western part of Austria, and in the northern part of Italy. It is recommended for localities where a great quantity of milk can not be obtained. The cheese is circular in form, about 16 inches in diameter and 4 inches high, and weighs from 40 to 80 pounds. It is cooked at a slightly lower temperature than the Emmental and is a little softer when ripened. It ripens more rapidly than the Emmental, being ready for market in about 4 months.

BAUDEN.

Baudenkäse is a sour-milk cheese made in the herders' huts in the mountains between Bohemia and Silesia in essentially the same manner as Harzkäse. It is made up in two forms, one conical with a diameter and a height of 3½ inches, and the other cylindrical, with a diameter of 5 inches and a height of 2½ inches. It is also known locally as Koppenkäse.

BELGIAN COOKED.

The milk which has been allowed to curdle spontaneously is skimmed and the curd heated to 135° to 140° F. and then placed in a cloth and allowed to drain. When dry it is thoroughly kneaded by hand and is allowed to undergo fermentation, which takes ordinarily from 10 to 14 days in winter and 6 to 8 days in summer. When the fermentation is complete, cream and salt are added and the mixture is heated gently and stirred until homogeneous, when it is put into molds and allowed to ripen for 8 days longer. A cheese ordinarily weighs about 3½ pounds. It is not essentially different from other forms of cooked cheese.

BELLELAY.

This is a soft rennet cheese made from whole milk and sometimes called Tête de Moine, and Monk's Head. This cheese originated with the monks of the Canton of Bern, Switzerland, in the fifteenth century, and is made exclusively in that locality at the present time.

The sweet milk is set at about 90° F. with sufficient rennet to coagulate it in 20 to 30 minutes. The curd is cut comparatively fine and is stirred while being heated slowly to a temperature of 110°. It is cooked much firmer than Limburg and not so firm as Emmental.

When cooked the curd is dipped into wooden hoops lined with cloth. The cheeses are pressed in rotation for a few minutes at a time, one press being used for a number of cheeses. After pressing, the cheeses are wrapped in bark for a couple of weeks, or until they are firm enough to require no support. They are cured in a moist cellar at a comparatively low temperature, as it is not desired to have eyes develop. The cheese when ready for market has a diameter of 7 inches and weighs from 9 to 15 pounds. It ripens in about 12 months and will keep for 3 or 4 years. It has a soft, buttery consistency and can be spread on bread for eating.

BERGQUARA.

This is a Swedish cheese resembling Gouda. It was known in Sweden in the eighteenth century.

BLEU.

The names Pâté Bleu and Fromage Bleu are applied to several kinds of hard rennet cheese made from cow's milk in imitation of Roquefort cheese in the southeastern part of France. Owing to the mottled, marbled, or veined appearance they are also designated Fromage Persillé. Among these are Gex, Sassenage, and Septmoncel. This name is also applied locally to several more or less distinct kinds made in the regions of the Auvergne and Aubrac Mountains and designated Bleu d'Auvergne, Cantal, Guiole or Laguiole, and St. Flour. Other cheeses of this order mentioned as made in France are Queyras, Champoléon, Sarraz, and Journiac.

BOUDANNE.

This is a French cheese made from cow's milk. The milk, either whole or skimmed, is heated to about 85° F., sufficient rennet is added to secure coagulation in 1 hour, and the curd is cut to the size of peas, stirred, and heated to 100° or above. After standing for 10 to 15 minutes the curd is pressed by hand and put into molds 8 inches in diameter and 3 inches in height. The cheeses are drained, turned frequently, salted, and ripened for 2 to 3 months.

BOX (FIRM).

This cheese, known in different localities where made as Hohenburg, Mondsee, and Weihenstephan, is made from whole cow's milk and is a rather firm rennet cheese. The flavor is said to be mild, but piquant. The milk is heated to 90° to 93° F. in a kettle, is colored with saffron, and set with sufficient rennet to curdle it in 20 to 25 minutes. The curd is cut up as fine as peas and the contents of the kettle are heated very slowly to a temperature of 105°, being stirred meanwhile. The fire is then removed and the curd allowed to settle for 5 minutes, when the whey is dipped off. The curd is then dipped into a cloth and from this is scooped into hoops. Light pressure is applied and in 15 minutes the cheese is turned, and the turning is repeated frequently for several hours. The cheese is kept in a well-ventilated room at 60° for 3 to 5 days, after which it is taken to the cellar. It is salted by rubbing or sprinkling salt on the surface. Ripening requires from 2 to 3 months. The cheese weighs from 1 to 4 pounds, and is undoubtedly similar to the Brick cheese of the United States.

BOX (SOFT).

This is a rennet cheese made from partially skimmed cow's milk and known locally as Schachtelkäse. It is a rather unimportant variety produced in Württemberg in a small locality called Hohenheim, a name which the cheese often takes.

In making this cheese the skimmed evening's milk is mixed with the whole morning's milk, or a part of the milk is skimmed with a centrifuge and is mixed with an equal volume of whole milk. The cheese is made in a copper kettle. The milk is warmed to 110° F., colored with saffron, and rennet added. It is allowed to stand for one to one and one-half hours before cutting. The curd is cut into rather coarse particles, after which it is allowed to stand for a few minutes, when the whey is dipped off, and for every 200 pounds of milk used a small handful of caraway seed is added. The curd is then dipped into hoops 6½ inches in height and the same in diameter. It remains in these hoops for 10 hours and is frequently turned, after which it is transferred to a wooden hoop only one-half as high, where it remains for 12 hours. The cheese is then sprinkled with salt and put in the ripening cellar, where it remains about 3 months.

A soft rennet cheese known as Fromage de Boîte is made in the mountains of Doubs, France, in the fall. It resembles Pont l'Évêque.

BRA.

This cheese is made by nomads in the region of Bra in Piedmont, Italy. It is a hard rennet cheese weighing about 12 pounds. The milk, which is partly skimmed, is heated to about 90° F., and sufficient rennet is added to coagulate it in 30 to 40 minutes. The curd is cut to the size of rice grains and the whey removed after about one-half of an hour. The curd is put into a form about 12 inches in diameter and 3 inches in height and subjected to pressure for 12 to 24 hours. It is salted by immersion in brine and also by sprinkling salt on the surface. The cheese is then ripened.

BRAND.

This is a German hand cheese weighing about one-third of a pound, made from sour-milk curd cooked at a little higher temperature than ordinarily practiced. The curd is salted and allowed to ferment one day. It is then mixed with butter, pressed into shape and dried, and finally placed in kegs to ripen, during which process it is moistened occasionally with beer.

BRICK.

The exact derivation of this name is not known. It may have been adopted because of the shape, or because of the fact that bricks are used almost exclusively for weighting down the press. Brick cheese is a rennet cheese made from unskimmed cow's milk, and is purely an American product. In characteristics it is about halfway between Limburg and Emmental. It has a strong, sweetish taste, a sort of elastic texture, and many small round eyes or holes. It is made about 10 by 6 by 3 inches in size. There are many factories making this product, especially in southern Wisconsin.

Perfectly sweet milk is set in a vat at 86° F. with sufficient rennet to coagulate it in 20 to 30 minutes. The curd is cut with Cheddar curd knives, and is then heated to 110° to 120° and stirred constantly. The cooking is continued until the curd has become firm enough so that a handful squeezed together will fall apart when released. The curd is then dipped into the mold, which is a heavy rectangular box without a bottom and with slits sawed in the sides to allow drainage. The mold is set on the draining table, a follower is put on the curd, and one or two bricks are used on each cheese for pressure. The cheeses are allowed to remain in the molds for 24 hours, when they are removed, rubbed all over with salt, and piled three deep. The salting is done each day for 3 days, after which the cheese is taken to the ripening cellar, which should have a temperature of from 60° to 65° and be comparatively moist. Ripening requires 2 months.

BRICKBAT.

This is a rennet cheese made as early as the eighteenth century in Wiltshire, England. It is made from fresh milk, to which a small portion of cream has been added. The milk is set at about 90° F. and allowed to stand 2 hours before the curd is disturbed. The curd is cut coarse, dipped into wooden forms, and light pressure applied. The cheese is said to be fit for consumption for one year after being made.

BRIE.

This is a soft rennet cheese made from cow's milk. The cheese varies in size and also in quality, depending on whether whole or partly skimmed milk is used. The method of manufacture closely resembles that of Camembert.

This cheese has been made in France for several centuries. Mention was made of it as early as 1407. It is made throughout France, but more extensively in the Department of Seine et Marne, in which it doubtless originated. This department contains Meaux, Coulommiers, and Melun, places noted for their manufacture of Brie cheese, though often under local names. More or less successful imitations of this cheese are made in other countries. It was estimated that 7,000,000 pounds of Brie cheese was sold in Paris during 1900. The export trade is also very important.

The milk used is usually perfectly fresh. It is not uncommon, however, to mix the evening's milk, when kept cool over night, with the morning's milk. Some artificial coloring matter is added to the milk, which is then set with rennet at a temperature of 80° to 85° F. After standing undisturbed for about 2 hours the curd is dipped into forms or hoops, of which there are three sizes in common use. The largest size is about 15 inches in diameter, the medium size about 12 inches in diameter, and the smallest size about 6 inches in diameter. These vary in height from 2 to 3 inches. After drainage for 24 hours without pressure being applied, the hoops are removed and the surface of the cheese is sprinkled with salt. Charcoal is sometimes mixed with the salt used. The cheese is then transferred to the first curing room, which is kept dry and well ventilated. After remaining in this room for about 8 days, the cheese becomes covered with mold. It is then transferred to the second curing room or cellar, which is usually very dark, imperfectly ventilated, and has a temperature of about 60° F. The cheese remains here for from 2 to 4 weeks or until the consistency and odor indicate that it is sufficiently ripened. The red coloration which the surface of the cheese finally acquires has been attributed to an organism designated *Bacillus firmatatis*. The ripening is due to one or more species of molds which occur on the surface and produce enzyms which in turn cause a gradual and progressive breaking down of the casein from the exterior toward the center. The interior of a ripened cheese varies in consistency from waxy to semiliquid and has a very pronounced odor and a sharp characteristic taste.

BRINSEN.

This cheese, known locally as Laudoch, Zips, Liptau, Siebenbürgen, Neusohl, Altsohl, and Klencz, is made in the Carpathian Mountains of Hungary from sheep's milk, or a mixture of sheep's and goat's milk.

The cheese is made in small lots, only 2 to 4 gallons of milk being used at one time. This is put into a kettle when fresh and sufficient rennet is added with the milk at a temperature of from 75° to 85° F. to secure coagulation in 15 minutes. The curd is broken up and the whey dipped and the curd is placed in a linen sack and allowed to drain for 24 hours. It is then cut into pieces and placed on a board, where with frequent turnings it is allowed to remain until it commences to get smeary, which requires about 8 days. The pieces are then laid one on top of another in a vessel holding from 40 to 60 pounds, where they remain for 24 hours, after which they are removed, the rind cut away, and the curd or partially cured cheese broken up in another vessel. After 10 hours salt is stirred in and the curd run through a mill which cuts it very fine, when it is packed in a tub with beech shavings.

BROCCIO.

This is a sour-milk cheese made from sheep's milk in Corsica. It is sometimes mixed with sugar and rum and made into small cakes. It is similar to Ziger.

BURGUNDY.

This cheese, known in France as Fromage de Bourgogne, is described as a soft, white, loaf-shaped cheese weighing about 4 pounds.

BUTTERMILK.

This cheese, which is made from the curd of buttermilk, is of somewhat finer grain than skimmed-milk cottage cheese, which it closely resembles. Buttermilk of 0.5 or 0.6 per cent acidity is run into a steam-heated vat or starter can, or placed in a pail which can be heated in a tub of hot water. The buttermilk is stirred and heated to 75° to 78° F., then covered and left for 1½ to 2 hours. The temperature is then raised to 140° F., and in about 1 hour the curd settles to the bottom. The whey is removed and the curd transferred to a draining cloth or bag for about 10 hours. It should be stirred occasionally while draining. When dry the curd is salted, put up in small packages, and wrapped in parchment paper.

CACIOCAVALLO.

This is a somewhat peculiar kind of cheese made from either whole or partly skimmed cow's milk. Various explanations have been made as to the origin of the name, which means literally horse cheese. One explanation offered is that the cheese was originally made in the region of Monte Cavallo, and another is that the imprint of a horse's head was made in each cheese as the trade-mark of the original manufacturer. The original home of this cheese was southern Italy, but it is now made extensively in northern Italy as well. The history of the cheese dates back several centuries.

The temperature of the coagulation of the milk with rennet varies greatly but is usually from 90° to 95° F. The time allowed for coagulation is also variable, being usually about one-half hour. The curd is cut very finely and sometimes allowed to ferment for 24 hours, when it is heated by means of very hot water, or more commonly hot whey, and subsequently worked by hand until all the whey is expressed and the curd becomes homogenous and capable of being drawn out into long threads. It is then molded into any desired shape and salted by immersion in brine for about 2 days. The cheeses are suspended in pairs from the ceiling and lightly smoked. The surface may be rubbed with olive oil or butter. They are kept in a cool, dry room until sold. As seen on the market they vary much in size and shape. On an average they weigh about 3 pounds. The most common shape is that resembling a beet, a constriction near the top being due to the string which is tied around the cheese for the purpose of hanging it up. This cheese is sometimes eaten while comparatively fresh, but is more frequently kept for months and then grated and used for flavoring soups and as an addition to macaroni and similar foods. A small quantity is imported into the United States.

CAERPHILLY.

This is a hard rennet cheese made in Wales from unskimmed cow's milk. The milk is set very sweet at a temperature of 85° F. with enough rennet to coagulate it in 1 hour. The curd is cut in ⅜-inch cubes and stirred for 1 hour without further heating. It is then put in cloths and subjected to light pressure for an hour and is again broken up fine and put to press, where it remains, with daily changing, for 3 days. During this time one-half ounce salt to each pound of curd is rubbed on the surface. Each cheese weighs about 8 pounds. The cheese requires about 3 weeks for ripening, at a temperature of 65° to 70°.

CAMBRIDGE.

This is a soft rennet English cheese made from cow's milk. Milk is set at 90° F. and rennet added. At the end of 1 hour the curd is dipped into molds without cutting and allowed to stand for 30 hours, when it is ready for eating.

CAMEMBERT.

This is a soft rennet cheese made from cow's milk. A typical cheese is about 4¼ inches in diameter and 1¼ inches thick and is usually found on the market in this country wrapped in paper and inclosed in a wooden box of the same shape. The cheese usually has a rind about one-eighth of an inch in thickness, which is composed of molds and dried cheese. The interior is yellowish in color and waxy, creamy, or almost fluid in consistency, depending largely upon the degree of ripeness.

Camembert cheese is said to have originated in 1791 in the locality from which it derives its name in the Department of Orne, in the northwestern part of France. The industry extended soon into Calvados, and these two Departments are still the principal seat of the industry. Cheese of the same type, however, is made in other parts of France and also in other countries; among these are Compiegne, Contentin, Pavillon, Soumaintrain, and Thury-en-Valois. Very successful results have been obtained at the Storrs Agricultural Experiment Station in Connecticut.

Camembert cheese is made from whole fresh milk or from milk which has been partly skimmed. The evening's milk may be skimmed and mixed with the fresh morning's milk. The temperature of setting is about 80° to 85° F., and the quantity of rennet added for this purpose is sufficient to secure the desired degree of firmness in about 2 hours. The curd is then transferred, usually with as little breaking up as possible, to perforated tin forms or hoops about 4¼ inches in diameter and the same in height. These rest upon rush mats which permit free drainage. The filling of the forms may be done at two or three times separated by short intervals allowed for the curd to settle. Each form holds the equivalent in curd of about 2 quarts of milk. After draining for about 18 hours, and preferably in a room having a uniform temperature of 65° to 70°, the cheese is turned. This is repeated frequently for about 2 days, when the cheese is removed from the forms and salted on the outside. Two or three days later the cheese is transferred to a well-ventilated room, where the ripening process begins. The cheese remains here for 15 to 20 days, during which time it is turned very frequently and the surface becomes covered with molds, which gradually produce a breaking down of the casein. It is then taken to the curing cellar, where the ripening process is completed in about 3 weeks, when it is packed and marketed.

CANQUILLOTE.

This is a skim-milk cheese made in the eastern part of France. It is also known locally as Fromagère and Tempête. The milk is allowed to coagulate spontaneously, after which it is heated gently and the whey drawn off. The curd is pressed in order to remove as much of the whey as possible, crumbled fine, and fermented at a temperature of about 70° F. for 2 or 3 days, during which time it is stirred frequently. When the cheese has acquired its characteristic taste it is melted with the addition of water, salt, eggs, and butter and put into molds of various kinds.

CANTAL.

This is a hard rennet cheese made from cow's milk more or less skimmed. Its manufacture is extensive in the Department of Cantal, France. It is also known as Auvergne or Auvergne Blue on account of its being manufactured in the region of the Auvergne Mountains. Locally the cheese is commonly known as Fourme. The cheese is doubtless a very old variety, and the method of manufacture has remained quite primitive. The milk, usually fresh but sometimes several hours old, is set with rennet at a temperature of about 85° F., the time allowed for coagulation being about 30 minutes. The curd is then cut very finely and the whey dipped off. The curd is subjected to pressure in order to remove as much of the whey as possible, and is allowed to ferment for 24 hours, which process is considered very important. The curd is then broken up by hand or by machinery and salted at the rate of 2.5 to 3 per cent. When thoroughly kneaded it is put into hoops about 14 inches in diameter. Pressure is applied for about 2 days, during which time it is turned very frequently. The cheese is next transferred to the curing cellar, where it remains for 6 weeks to 6 months. The yield of cheese is usually 10 to 11 per cent of the weight of the milk. A ripened cheese weighs from 40 to 120 pounds.

CHAMPOLÉON.

Champoléon, or Queyras, is a hard rennet cheese made from skim milk in the Department of Hautes-Alpes, France.

CHAOURCE.

This is a soft whole-milk rennet cheese resembling Camembert and deriving its name from the village of Chaource, in the Department of Aube, France. It is about 4 inches in diameter and 3 inches thick.

CHASCHÖL DE CHASCHOSIS.

This cheese is made in the Canton of Grisons, Switzerland. It is a hard rennet cheese made from skimmed cow's milk. The cheeses are 18 to 22 inches in diameter, 3 to 4 inches high, and weigh from 22 to 40 pounds.

CHEDDAR.

This cheese is so named from the village of Cheddar in Somersetshire, England, where it was first made. It is a comparatively old cheese, though the genuine Cheddar process as it is now known is not old. Cheddar cheese is an exceedingly popular variety, being much used as a food product in America and England. It is probably the most important of all cheeses as regards the quantity made annually. The term Cheddar as used at the present time applies usually to a process of making rather than to any particular shape of cheese. The name, however, is occasionally used to designate a certain size of cheese 14 to 16 inches in diameter, and weighing from 60 to 100 pounds. Cheese made by the Cheddar process has, however, many different shapes with distinguishing names, such as Flats, which have the same diameter as the Cheddar size, but weigh only 30 to 40 pounds; Daisies, which are 12 inches in diameter and weigh 20 pounds; Young Americas, which are 8 inches in diameter and weigh 8 to 12 pounds; Long Horns, which are 5 inches in diameter and weigh 12 pounds; and Squares, which are of various sizes and usually 3 to 4 inches thick. The cheese may be white or colored yellow, and it may be almost fresh or thoroughly ripened and broken down. It is made from sweet cow's milk, which may be skimmed, partly skimmed, or unskimmed. When made from unskimmed milk the cheese is called "full cream;" when otherwise, it is called "part skim" or "skim."

The milk, morning's and evening's mixed, is set at 85° F. with sufficient rennet to coagulate to the proper point in from 25 to 40 minutes. At the time of setting the milk should have an acidity of about 0.18 to 0.20 per cent. Color may or may not be used. The curd is cut when it breaks evenly before the finger. The cutting is done with curd knives. These knives are made up of blades set about one-third of an inch apart in frames. In one frame the knives are set perpendicularly and in the other horizontally. When well cut the curd is in uniform cubes of about one-third of an inch.

After cutting the curd is heated slowly and with continued stirring until it reaches a temperature of from 96° to 108°. With the use of mechanical agitators, as is the common practice, the curd should be heated about 4 degrees higher than when stirring is done by hand. After heating the stirring is continued intermittently until the curd is sufficiently firm. This is determined by squeezing a handful, which should fall apart immediately on being released. The whey is then drawn. At the same time the acid should have reached about 0.20 per cent or one-fourth of an inch on the hot iron, which latter is determined by measuring the length of strings when the curd is touched to a hot iron. The curd is then matted about 4 inches deep, sometimes in the bottom of the vat, sometimes on racks covered with a coarse linen cloth. After it has remained here long enough to stick together it is cut into rectangular pieces easy to handle, which are turned frequently and finally piled two to four deep; in the meanwhile the temperature of the curd is kept at about 90°. When the curd has broken down until it has the smooth feeling of velvet, which requires from one to three hours, it is milled by means of a machine, which cuts it into pieces the size of a finger. It is then stirred on the bottom of the vat until whey ceases to run, which requires from one-half to one and one-half hours, when it is salted at the rate of 2 to 2½ pounds of salt to 100 pounds of milk. It is then ready to put in press. The curd is put into tinned iron hoops of the proper size, which are lined with cheese-cloth bandages. The hoops are put in presses and great pressure is applied by means of screws. The next morning the cheese is removed from the hoops and put on shelves in a curing room. Formerly the cheese was kept in a curing room as long as 6 months, but at the present time it is covered with a coat of paraffin and put in cold storage when 3 to 12 days of age. There is a growing demand on the part of consumers for mild cheese, and consequently ripening must be carried on at a temperature below 50°.

An important point in the process of manufacturing Cheddar cheese is the development of the desired amount of acid. A maximum quantity in the whey that can be developed without injuring the texture of the cheese is aimed at, and the proper breaking down of the curd before milling and salting is attributed to the acid. It is very probable that too much weight has been placed on the desirability of a maximum development of acid, and that practically as good cheese can be produced without the high acid.

Some of the details in the manufacture of Cheddar cheese are varied to some extent, and other names may be used to designate the cheese so made. A stirred curd cheese is one where the curd particles are not allowed to mat together after the whey is drawn. The curd is stirred at intervals to prevent this matting process, but it differs from the sweet curd cheese, as acid is allowed to develop before salting and pressing. Formerly there was a comparatively large quantity of stirred curd cheese made, but there is very little, if any, made at the present time.

A washed curd cheese varies from the regular Cheddar process in having the milled curd subjected for a short period to cold water. This process is evidently practiced to force the curd to take up a small percentage of the water and increase the yield. It results in a cheese which apparently breaks down or ripens much more rapidly than cheese made in the ordinary way. This ripening is very likely not due to the excess of moisture but to some other unexplained reason. Some States have prohibited the use of the State brand on washed curd cheese.

CHESHIRE.

This cheese is one of the oldest and most popular of the English varieties. It is a rennet cheese made from unskimmed cow's milk, and is named for Chester County, England, where it is largely produced. It is made in cylindrical shape from 14 to 16 inches in diameter, and weighs 50 to 70 pounds. In making this cheese sufficient annatto is used to give the product a very high color. The process of manufacture varies in detail in different sections. Perfectly sweet milk, night's and morning's mixed, is set at a temperature of from 75° to 90° F. The curd is cut in 1 hour, usually with an instrument in which knives are set in a frame to cut cubes 1 to 1½ inches square. This is pushed down through the curd and finally worked back and forth at an angle. This is continued until the particles of curd are the size of peas, which requires about 1 hour. The curd is then allowed to settle and mat on the bottom of the vat for about an hour, when it is rolled up to one end, weighted down, and the whey drawn after the desired degree of acidity has been obtained. The curd is cut in pieces the right size to handle and is piled on racks. It is then run through a curd mill, salted at the rate of 3 pounds to 1,000 pounds of milk, and put into a hoop having a number of holes in the side through which skewers can be thrust into the cheese to promote drainage. The cheese in the hoop is put in a heated wooden box called an oven, and sometimes light pressure is applied, the pressure increasing gradually until it reaches about 1 ton. The curing cellar or room is about 60° to 65°. From 8 to 10 months is required for thorough ripening.

CHESHIRE-STILTON.

This is a combination of the Cheshire and Stilton varieties of cheese in which the general characteristics of size and shape and manufacture of the Cheshire is retained, and a growth of the mold peculiar to Stilton is secured. The mold is secured by keeping out each day a small portion of curd and mixing it with some curd in which the mold is growing well.

CHIAVARI.

This is a sour-milk cheese made in the region of Chiavari, Italy, from whole cow's milk. It is also known as Cacio Romano. A hard rennet cheese made in the same region is also known by this name.

COMMISSION.

This cheese is made in Holland and resembles Edam in the process of manufacture, but it has a slightly different shape, being flattened at the ends. It is said to be made from whole cow's milk.

COTHERSTONE.

This is a rennet cow's-milk cheese made in Yorkshire, England, and resembles the well-known Stilton cheese of that country. It is a local product manufactured only on a small scale. It has also been known as Yorkshire-Stilton.

COOKED.

This kind of cheese is so called because the curd is heated to the melting point in its manufacture. It is made from fresh curd prepared by breaking up and heating the curd of sour clabbered milk. When cooled sufficiently this curd is placed in a receptacle and allowed to stand for 3 or 4 days until it has become colored throughout. It is then put into a kettle over a fire; salt, milk, and usually caraway seed are added, and the whole is stirred vigorously until it becomes of the consistency of thick molasses, or until it strings when a spoon is withdrawn. The mass can then be put into molds until it becomes cold, or placed in a vessel for keeping. It gets hard with cooling and will retain the shape of the mold.

Cooked cheese, made in northern Germany, is called Topfen, and a similar product made in Sardinia is called Freisa, and Paneddas. The same kind of cheese made in Belgium is called Belgian cooked cheese. Similar kinds are made in other countries.

COTTAGE.

This is a sour-milk cheese made extensively in this country, where it is often called Dutch cheese, and Smearcase. It is manufactured usually in a very small way, but occasionally it is made in large factories. Skim milk is allowed to sour and the curd is then broken up and held at a temperature of about 100° F. for 3 to 4 hours, or until it has become sufficiently firm. The whey is then drained off and the curd placed under slight pressure for a time. The curd is either consumed immediately or is packed in tubs and placed in cold storage. It is prepared for eating by moistening with either milk or cream. Sometimes it is made up into shapes and wrapped in tin foil. No ripening is ever allowed.

COULOMMIERS.

This is a small-sized Brie cheese 5 to 6 inches in diameter and 1 inch in thickness, and weighing about 1 pound. It is made in the region of Coulommiers, France.

CREAM.

Genuine cream cheese is made from a rich cream thickened by souring, or from sweet cream thickened with rennet. This is put in a cloth and allowed to drain, the cloth being changed several times during the draining, which requires about 4 days. It is then placed on a board covered with a cloth, sprinkled with salt, and turned occasionally. It is ready for consumption in from 5 to 10 days.

Another variety of cream cheese is made from cream with a low content of fat (12 to 15 per cent). The cream is curdled with rennet, broken up to allow a part of the whey to escape, and is then mixed and worked into almost a paste. This is then molded into pieces weighing 2 to 4 ounces, which are wrapped in tin foil and placed on the market without curing. It is a very mild and a very rich cheese and is manufactured on an extensive scale by a few large factories in the United States.

A so-called double-cream cheese, known in France as Fromage Double Crème, is made by coagulating a mixture of milk and cream and putting this into a cloth and allowing it to drain thoroughly, when it is salted, kneaded, and molded into any desired shape. It is eaten fresh. The Gervais is a cheese of this kind.

A French cream cheese, Fromage à la Crème, is prepared by mixing sweet cream with well-ripened sour-milk curd or rennet curd. Another French cream cheese, which contains considerable salt as a preservative, is known as Demi-sel. There are in addition several cream cheeses having specific names, such as Philadelphia Cream.

In the United States cream cheese is usually sold under some trade name, such as Philadelphia Cream. The manufacturers in this country have in some cases attempted to vary this cheese by the use of some flavoring matter or condiment.

CREUSE.

This is a skim-milk farm cheese made in the department of the same name in France. Coagulation is secured either by the addition of a small quantity of rennet or by heating the sour milk. When set with rennet the period required is usually 12 hours. The curd is put into earthenware molds about 7 inches in diameter and 5 to 6 inches in height, the bottom and sides being perforated. After draining for several days the cheese is removed from the molds, salted, and turned frequently. It becomes in time very dry and hard and may be preserved for a year or longer. The cheese is also ripened by placing in tightly closed receptacles lined with straw, in which case it becomes yellow and soft and acquires a very pronounced taste.

CRISTALINNA.

This is a hard rennet cheese made from cow's milk in the Canton of Graubunden, Switzerland.

DAMEN.

This is a soft uncured rennet cheese made from cow's milk in Hungary and is much in demand in the markets of Vienna. It is sometimes known as Gloire des Montagnes.

DANISH EXPORT.

This cheese is made in some of the creameries of Denmark to furnish an outlet for the skim milk and the buttermilk. In the process of manufacture as high as 15 per cent of fresh buttermilk is added to the skim milk. The mixture is set at 98° F. with sufficient rennet to coagulate in 25 minutes. The curd is carefully and evenly cut, stirred for a few minutes, dipped into forms having rounded bottoms, kneaded, pressed down, and finally covered with a board, upon which a weight is placed. Twelve hours later the cheeses are placed in a brine tank for 24 hours, when they are taken out and covered with salt for a short time. They are then transferred to the ripening room, where the temperature is about 55°, and are turned and wiped with a cloth every day for 5 weeks. The cheeses are cylindrical in shape and are small and flat.

DERBYSHIRE.

This is a hard rennet cheese made from whole cow's milk in Derbyshire, England. It is cylindrical in shape and about the size of the Cheshire, though often smaller. It is made usually in farm dairies, and because of this fact the size varies with the size of the herd. The quality also varies to such an extent that very few really good cheeses can be found. Night's milk in which the development of acid has been prevented as much as possible is mixed with the morning's milk, and the whole is set at a temperature of 80° F. The setting period is 1 hour, and the curd is allowed to become very firm before cutting. The curd is cut to the size of a pea and after being allowed to settle is piled in the center of the vat, where, after the whey is removed, it is subjected to light pressure. The curd is cut and again piled and heavier pressure applied. This is repeated until the curd reaches a certain degree of firmness, when it is run through a mill and salted at the rate of 1 pound of salt to 1,000 pounds of milk. It is then put in a press for 1 hour, when it is removed and the surface of the cheese scalded for 1 minute in water heated to 150°. It is put back in the press for 5 hours, the pressure applied being gradually increased, when it is salted on the surface and again pressed. The pressing continues for 3 days, the cheese being salted each day. The curing room is kept preferably at 60°, and the time required for curing is from 3 to 4 months.

A cheese called Gloucester made in the county of Gloucester, England, is said to be identical with Derbyshire cheese. Double Gloucester is identical with single Gloucester in all respects but size. It is twice as thick as a single Gloucester, hence the name. Wiltshire, Leicestershire, and Warwickshire cheeses belong to the Derbyshire type.

DEVONSHIRE CREAM.

In making this cheese the cream is allowed to rise for several hours, when the milk with the layer of cream is scalded. It is then set away for a short time in order that the layer of cream may harden. The cream is then put into small molds and placed upon straw mats to drain. After becoming hard enough to retain its shape it is ready for market.

DORSET.

Dorset, or Blue Dorset, is a cheese resembling in character and method of manufacture the better known Stilton. It is named from Dorsetshire, England, in which it is made.

DOTTER.

This cheese is said to have been made by G. Leuchs, in Nurnberg, by mixing the yolk of eggs with skim milk and making this mixture into cheese in the usual way.

DRY.

This cheese, known also as Sperrkäse and Trockenkäse, is made in the eastern part of the Bavarian Alps and in the Tyrol, in the small dairies of those localities. It is an extremely simple product made for home consumption, and is made only in the winter season, when the milk can not be profitably used for other purposes. As soon as the milk is skimmed it is put into a large kettle which can be swung over a fire. Here it is kept warm until it is thoroughly thickened from souring. It is then broken up and cooked quite firm. A small quantity of salt and sometimes some caraway seed are added, and the curd is put into forms of various sizes. It is then placed in a drying room, where it becomes very hard, when it is ready for eating.

DUEL.

This is a soft cured rennet cheese made from cow's milk. It is an Austrian product, 2 by 2 by 1 inches in size.

DUNLOP.

This was formerly the national cheese of Scotland, but it has been almost superseded by the Cheddar, which it resembled.

EDAM.

This is a hard rennet cheese produced in Holland; it is also known as Katzenkopf, Tête de Maure, and Manbollen. The best of the product is made of unskimmed cow's milk, but much of it at the present time is made from milk which has had at least one-half of the fat removed. The cheeses are round and are colored deep red on the surface or wrapped in tin foil.

The perfectly fresh milk is set at 90° to 95° F. Color is added and sufficient rennet is used to coagulate the milk in 15 minutes. The curd is cut and after a very short stirring is allowed to settle to the bottom, when the whey is dipped off. The curd is gathered in a pile and pressure is applied for a short time to expel the whey. Care is taken in the meanwhile that the curd does not get below 82° or above 90°. The curd is then ready for the press. Sometimes wooden molds are used, but the best are made of iron. An attempt is made to put just sufficient curd into the mold to make a perfect sphere when pressed. When the mold is half full a little salt is added. When the mold is full, it is pressed lightly until the cheese will hold its form, when it is taken out and immersed in water for two minutes at 125°. The cheese is then put in the press, where it remains for 12 hours. It is then removed from one mold and placed in another form resembling the mold but without a cover, and having a hole leading from the bottom. The cheese is salted by rubbing salt on the surface. Sometimes it is kept in a salt bath for a day before putting salt on the surface. Following the salting, the cheese is washed in hot whey, and the surface is scraped smooth. It is then taken to the ripening cellar, which should have a temperature of between 50° and 70°. Here it is turned daily for a time and finally twice a week. In the meanwhile it is occasionally moistened with cold water or fresh beer. When the cheese is 1 month old it is washed in water at

70° for 20 minutes and then placed in the sun to dry, after which it is rubbed with linseed oil. Before shipping the cheese is colored, usually red, but for some markets it is colored yellow with annatto. This coloring is done with a watery solution of litmus and Berlin red, or with carmine. A considerable quantity of this cheese is imported into the United States. At the present time some Edam cheeses are inclosed in air-tight tins for export.

ELBING.

This is a West Prussian hard rennet cheese made from cow's milk which, during the winter, is partly skimmed, but at other times left whole. It is known also as Werderkäse and Niederungskäse. Enough rennet is added to the milk at a temperature of 80° F. to coagulate it in from 15 to 30 minutes. The curd is cut and cooked to 100°, salted in the granular state, and pressed for 12 hours. A cheese is 10 to 20 inches in diameter and 3 to 4 inches in thickness. Ripening requires about 1 month at a temperature of 75°.

EMMENTAL.

This a hard rennet cheese made from unskimmed cow's milk, and has a mild, somewhat sweetish flavor. It is characterized by holes or eyes which develop to about the size of a penny in typical cheeses and are situated from 1 to 3 inches apart. Cheese of the same kind made in the United States is known as Domestic Swiss, and that made in the region of Lake Constance is called Algau Emmental. Other local names are Bellunese, Formaggio Dolce, Fontine d'Aosta, and Thraanen.

Emmental cheese originated in Canton Bern, Valley of Emmental, Switzerland. It is a very old variety. In the middle of the fifteenth century a cheese probably of this type was manufactured in the Canton of Emmental. In the middle of the seventeenth century the industry was well developed and genuine Emmental cheese was being exported. In 1722 its manufacture under the name of Gruyère is recorded in France, two cooperative societies having been organized for this purpose.

Emmental cheese is now manufactured in every civilized country. In the United States there are many factories, located principally in Wisconsin, New York, and Ohio. In Switzerland the greater part of the milk produced is made into this product, and large districts in France and northern Italy are devoted to its manufacture. The best of the product made in Switzerland is exported, about 5,000,000 pounds coming to the United States annually. The imported cheese sells in this country at about 25 cents a pound wholesale, and the domestic cheese sells at about 14 cents. Practically as good cheese can be manufactured in the United States as in Switzerland, but prejudice, combined with the fact that much of the domestic product is sold as imported, has held the price at a low level.

There is a slight difference in manipulation of the milk in making Emmental cheese in this country as compared with Switzerland. In the latter country the evening's and morning's milk are made up together, while in the United States it is popularly believed that the evening's milk must be made into cheese immediately after milking, as is done with the morning's milk.

In making the cheese in Switzerland the evening's milk is skimmed; the fresh morning's milk is heated to 108° to 110° F. and the cream from the evening's milk is added and well stirred in. The cooled evening's milk with a little saffron is then added and the whole is mixed. The milk is then brought to a temperature of 90° in summer and 95° in winter and sufficient rennet is added to coagulate the milk in 30 to 40 minutes. The whole process is carried through in a huge copper kettle holding 300 gallons of milk. The rennet used is the calf's stomach soaked for 24 hours in whey. When the milk has thickened to almost the desired point for cutting, which is practically the same as for ordinary American or Cheddar cheese, the thin surface layer is scooped off and turned bottom side up. This is supposed to aid in incorporating the layer of cream with the cheese. The curd is then cut very coarse by means of a so-called harp. The cheese maker with a wooden scoop in each hand then draws the mass of curd toward him, that lying on the bottom of the kettle being brought to the surface. At this point the cheese maker and an assistant commence stirring the curd with the harp, a breaker having first been fitted to the inside of the kettle to interrupt the current of the whey and curd. The harps are given a circular motion and cut the curd very fine—about the size of wheat kernels or smaller.

After this stage is reached heating is commenced. In Switzerland all of the heating until recently was done over an open fire, the kettle being swung on a large crane, and most of the factories have the same method at the present time. In this country the same method was followed in the early days of the industry, but at the present time inclosed fireplaces into which the kettle can be swung and doors closed to retain the heat are largely employed. This takes away much of the discomfort of the operation. In a few instances the kettles are set in cement and an iron car containing the fire is run under it. The more modern factories employ steam, and this appears to be the most satisfactory way. When the heating is begun the contents of the kettle are brought rapidly to the desired temperature, which may be from 126° to 140°, the higher temperature often being necessary to get the curd sufficiently firm. The stirring in the meanwhile continues for about 1 hour, with slight interruptions near the end of the process when the curd has become so firm that it will not mat together. The end of the cooking is determined by the firmness of the curd, which is judged by matting a small cake with pressure by the hands and noting the ease with which this cake breaks when held by the edge.

When the curd is sufficiently firm the contents of the kettle are rotated rapidly and allowed to come to standstill as the momentum is lost. This brings all the curd into a cone-shaped pile in the center of the kettle. One edge of a heavy linen cloth resembling burlap is wrapped around a piece of hoop iron and by this means the cloth is slipped under the pile of curd. The mass of curd is then raised from the whey by means of a rope and pulley and lowered into a cheese hoop on the draining table. These hoops are 4 to 6 inches deep and vary greatly in diameter. The cloth is folded over the cheese, a large follower is put on top, and the press is allowed to come down on the cheese. The press is usually a log swung at one end and operated by a double lever. Pressure is continued for the first time just long enough for the curd mass to retain its shape. The hoop is then removed, the cheese turned over, and a dry cloth substituted. The cheese is allowed to remain in the press about 24 hours, during which time it is turned and a dry cloth substituted several times (six or more).

At the end of the pressing the curd should be a homogeneous mass without holes. The cheese is then removed to the salting board, covered with a layer of salt, and turned occasionally. In a day or two it is put in the salting tank in a brine strong enough to float an egg; it remains here at the discretion of the cheese maker for 1 to 4 days. Often no brine tank is used with Emmental cheese.

The cheese is then taken to the curing cellar. In the best factories two or more cellars with different temperatures are available, and the cheeses are placed in them according to the way the cheese maker thinks their development requires. If it appears that the cheese may develop too fast and have too many and too large eyes, the cheese is placed in a cool cellar; if the reverse is true, a warm cellar is selected. The cellars vary in temperature from 55° to 65°, though in extreme cases 70° or a little higher may be used. While the cheeses are in the ripening cellar, which in Switzerland may be 6 to 10 months or longer, and in the United States 3 to 6 months, they should be turned and washed every other day for the first 2 or 3 months and at longer intervals subsequently, and at the same time a little coarse salt is sprinkled on the surface. In a few hours this salt has dissolved, and the brine is spread over the surface with a long-handled brush.

The cheeses are very large, about 6 inches in thickness and sometimes as much as 4 feet in diameter, and weigh from 60 to 220 pounds. In shipping, a number of them are placed in a tub which may contain 1,000 pounds of cheese. Sometimes Emmental cheese is made up in the form of blocks instead of like millstones. The blocks are about 28 inches long and 8 inches square in the other dimensions.

ENGADINE.

This is made in the Canton of Graubünden, Switzerland, and is a rennet cheese made from unskimmed cow's milk.

ENGLISH DAIRY.

This name is applied to a very hard cheese, made in the same general way as Cheddar, but cooked much more. This cheese has been made mostly in the United States. It is used for culinary purposes.

ÉPOISSE.

This is a soft rennet cheese made from whole or partly skimmed milk in the Department of Côte d'Or, France.

ERVY.

This is a soft whole-milk rennet cheese resembling Camembert and deriving its name from the village of Ervy, in the Department of Aube, France. A cheese is about 7 inches in diameter, 2½ inches thick, and weighs about 4 pounds.

FARM.

This cheese, made in France, and known variously as Fromage à la Pie, Mou, Maigre, and Ferme, is essentially the same as our Cottage cheese. The method of making is very simple. When the skimmed milk has become curdled the whey is poured off and the curd kneeded and molded into various sizes and shapes. Draining is sometimes hastened by placing a board and weight upon the curd. Salt and sometimes sweet cream are added. The cheese is consumed usually on the farm where made, either while fresh or after it has undergone fermentation.

FILLED.

Filled cheese is the name applied to cheese from which the butter fat has been removed and foreign fats added. The foreign fat is added by stirring it violently in the milk and setting with sufficient rennet to coagulate quickly. The rest of the manufacture is the same as for Cheddar cheese. Filled cheese was very extensively manufactured in the United States for a number of years, but State and Federal laws have made this no longer practical. Many of the European varieties of cheese are counterfeited or adulterated in the same manner.

FLOWER.

This cheese is so named because it is made with the addition of the petals of various kinds of flowers, such as roses and marigolds. It is a soft cured rennet cheese made in England from whole cow's milk.

FORMAGELLE.

This is a small soft ripened rennet cheese made from cow's milk in the northwestern part of Italy.

FORMAGGINI.

This name is applied to several kinds of small Italian cheeses. The kind designated Formaggini di Lecco is a small cylindrical dessert cheese, weighing about 2 ounces, made in the region of Lecco, in Lombardy. It is consumed while fresh and sweet and at all stages of ripening until it becomes very piquant. Sometimes salt, pepper, sugar, and cinnamon are mixed with this cheese, and occasionally oil and vinegar are added. The method of manufacture is not essentially different from that of other soft cheeses. Cow's milk is used with the addition at times of some goat's milk. Rennet is added to the warmed milk, which is then allowed to stand for 24 hours at a temperature of about 55° F. The curd, with as little breaking up as possible, is allowed to drain for 3 to 4 hours, when it is salted and put into cylindrical molds about 1½ inches in diameter and 2 inches high.

FROMAGE FORT.

Several kinds of cooked cheese prepared in France are known by this name. In the Department of Ain, Fromage Fort is prepared by melting well-drained skim-milk curd, putting the melted mass into a cloth, and subjecting it to pressure and afterwards burying it in dry ashes in order to remove as much of the whey as possible. The mass is then grated fine and allowed to ferment for 8 to 10 days, after which milk, butter, salt, pepper, wine, etc., are added to it, and the mixture is allowed to undergo further fermentation.

Canquillote, Cancoillotte, or Fromagère, prepared in the eastern part of France, is a cheese of this kind, as is also the Fondue, or cooked cheese, of Lorraine.

GAMMELOST.

Gammelost is made in Norway from skimmed sour milk. The milk is cooked or warmed in a kettle and allowed to stand for 1 hour while the precipitated casein gathers at the bottom. This is taken up in a cloth, and the whole is put into a form where light pressure is applied. The cheese still in the cloth in the form is put in the hot whey for an hour, when it is again placed under pressure for a short period. It is put in a warm place and turned daily. At the end of 14 days it is packed in a chest with wet straw. The cheeses vary in weight from 24 to 65 pounds.

GAUTRAIS.

This is a cylindrical cheese weighing about 5 pounds and very closely resembling Port du Salut. It is made in the Department of Mayenne, France.

GAVOT.

This cheese is made from cow's, sheep's, or goat's milk in the Department of tes-Alpes, France.

GEHEIMRATH.

This is a cheese made in small quantities in Holland. It resembles a small Gouda cheese in quality and process of manufacture. It is colored a deep yellow.

GÉROMÉ.

This is a soft rennet cheese made in the mountainous regions of the Vosges, France. The name is a corruption of Gérardmer, a village in the region where the cheese has been made for at least 50 years. The variety is very similar to Münster, but not so well known.

Cow's milk is used almost exclusively, though at times a little goat's milk is added. The fresh milk is set with rennet at a temperature of about 80° to 90° F. In about one-half hour after adding the rennet the curd is cut into rather large cubes and allowed to stand for about 1 hour when the whey is dipped off. The curd is then put into cylindrical forms or hoops 6 to 7 inches in diameter. Formerly these were made of wood, one being placed upon another, making a total height of 14 to 15 inches. They are now being made also on tin and in various sizes. The cheeses are turned after 6 hours and again after 12 hours. During the next 2 or 3 days they are turned twice daily, the hoops being changed each time. A room temperature between 60° and 70° is desired during this process. The cheeses are then salted, the amount of salt used being from 3 to 3.5 per cent of the weight of the cheese.

The cheeses are then placed in a well-ventilated room for several days and when sufficiently dry are transferred to the curing cellar. Here they are turned frequently and worked with warm salt water to prevent the growth of molds. Ripening requires from 6 weeks to 4 months, depending upon the size of the cheeses, which vary in weight from one-half pound to 5 pounds or more. Anise is sometimes incorporated with the curd before putting into the forms. Such cheese when old often has a greenish appearance.

GERVAIS.

This is a French cheese made from a mixture of whole milk and cream. The mixture is set with rennet at about 65° F., the time required being about 12 hours. The curd is then inclosed in cloth and hung up to drain. When sufficiently dry it is salted and pressed into molds. The molds are soon removed and the cheese is wrapped in paraffin paper. The cheese is usually consumed while fresh, but may be kept for several days.

GEX.

This is a hard rennet cheese made from cow's milk. It belongs to the class of blue or marbled cheese known in France as Fromage Persillé, which includes Sassenage, Septmoncel, and several other kinds resembling Roquefort. It is made principally in the southeastern part of France and derives its name from the town of Gex, in the Department of Ain, where the cheese has been made for at least 60 years. There has been little tendency for the industry to extend to other regions than that in which it originated, and even here it is said to be diminishing.

Rennet is added to the fresh milk as soon as possible after milking. The time allowed for coagulation is 1½ to 2 hours. The curd is then broken up and stirred until the mass is in a semiliquid condition, when it is allowed to stand for about 10 minutes. After the curd has settled to the bottom of the vat the whey is drained off. The curd is then worked by hand, salted lightly, and put into hoops about 12 inches in diameter and 5 inches in height. In about 1 hour the cheese is turned and a disk and weight placed upon it. The turning is repeated three or four times a day, the hoops being removed at the end of the first day. After salting, the cheese is taken to the curing room, where it soon acquires a bluish appearance, due to the development of a penicillium. This mold is not introduced into the interior of the cheese during making by means of mottled bread, as is the case with Roquefort cheese. The ripening process, which requires from 3 to 4 months, is completed in cellars or natural caves. A ripened cheese weighs from 14 to 15 pounds.

GISLEV.

This is a hard rennet cheese made in Denmark from skimmed cow's milk.

GLUMSE.

This cheese is made from sour skimmed milk in western Prussia. The thickened milk is placed over a slow fire at about 105° F. and is cooked as long as any whey is expelled. The cooking may be done by pouring hot water into the milk. After cooking, the curd is removed from the whey with a perforated dipper and is allowed to drain in a hair sieve. Milk or cream is added to the cheese just before eating. This is evidently a cottage cheese.

GOAT'S MILK.

There are a large number of goat's-milk cheeses, many of which are not designated by local names. In France some of these are known by the names Chevret or Chevrotin, in Italy as Formaggio di Capra, and in German-speaking countries as Ziegenkäse or Gaiskäsli. Among those in France to which local names have been attached are Gratairon, Lamothe, and Poitiers.

The Gaiskäsli is a soft cheese made in certain parts of Germany and Switzerland. The milk is set with sufficient rennet to coagulate it in about 40 minutes. The curd is then broken up, stirred, and dipped into cylindrical molds about 3 inches in diameter. The mold is filled sufficiently to make a cheese 1½ to 2 inches thick and weighing one-half pound. The mold is set on a straw mat which allows the whey to drain freely, and salt is sprinkled on the surface. In 2 days the cheese is turned, and the other surface is salted. The cheese requires about 3 weeks to ripen and is said to have a very pleasant flavor.

A kind of cheese is made in Norway by drying goat's milk by boiling, fresh milk or cream sometimes being added during the process.

GORGONZOLA.

This variety, known also as Stracchino di Gorgonzola, is a rennet Italian cheese made from whole cow's milk. The name is taken from the village of Gorgonzola, near Milan, but very little of this cheese is now made in that immediate locality. The interior of the cheese is mottled or veined with a penicillium much like Roquefort, and for this reason the cheese has been grouped with the Roquefort and Stilton varieties. As seen upon the markets in this country, the surface of the cheese is covered with a thin coat resembling clay, said to be prepared by mixing barite or gypsum, lard or tallow, and coloring matter. The cheeses are cylindrical in shape, being about 12 inches in diameter and 6 inches in height, and as marketed are wrapped in paper and packed with straw in wicker baskets.

The manufacture of Gorgonzola cheese is an important industry in Lombardy, where formerly it was carried on principally during the months of September and October, but with the establishment of curing cellars in the Alps, especially near Lecco, the manufacture is no longer confined to this season.

The milk used in making this cheese is warmed to a temperature of about 75° F. and coagulated rapidly with rennet, the time required being usually from 15 to 20 minutes. The curd is then cut very finely and inclosed in a cloth and drained, after which it is put into hoops 12 inches in diameter and 10 inches high. It was formerly the custom to allow the curd from the evening's milk to drain over night and to mix it with the fresh warm curd from the morning's milk prepared in the same way. The curd from the evening's milk and that from the morning's milk, crumbled very fine, were put into hoops in layers with moldy bread crumbs interspersed between the layers. The cheese is turned frequently for 4 or 5 days, the cloths being changed occasionally, and is salted from the outside, the process requiring about 2 weeks. It is then transferred to the curing rooms, where a low temperature is usually maintained. At an early stage in the process of ripening the cheese is usually punched with an instrument about 6 inches long, tapering from a sharp point to a diameter of about one-eighth inch at the base. About 150 holes are made in each cheese. This favors the development of the penicillium throughout the interior of the cheese. Well-made cheese may be kept for a year or longer. In the region where made much of the cheese is consumed while in a fresh condition.

GOUDA.

This is a Holland cheese made from whole or partly skimmed cow's milk. It is round and weighs 10 to 45 pounds. The milk, to which coloring matter has been added, is set at 91° F. with sufficient rennet to coagulate it in 15 minutes. The curd is cut or broken with a wooden scoop, a harp, or an American cheese knife. It is allowed to stand for a minute and the whey is dipped off. Hot whey or hot water is poured on the mass of curd until the whole has reached a temperature of 104° to 110°. When the curd squeaks or whistles when it is crushed between the teeth the whey or water is dipped off and the curd is stirred and piled where it will drain well. The curd is then thoroughly kneaded and sometimes lightly salted. After salting, the curd is put into round molds and placed in a press, where it remains for 24 hours with increasing pressure. The cheese is then salted either by immersion in brine or by rubbing salt on the surface. The salting continues for 4 to 8 days. After salting, the cheese is washed with hot whey. It is then transferred to the ripening cellar, where it is turned daily for several days and finally once a week until ripened. It is ready for consumption in 6 to 8 months. When the cheese is a few days old it is washed with water and colored with saffron. Some of this cheese is shipped to the United States. As seen in this country, each cheese is covered with an animal tissue said to be a bladder.

GOURNAY.

This is a soft rennet cheese which derives its name from the village of Gournay in the Department of Seine-Inférieure, France, where it is made. It is about 3 inches in diameter and three-fourths inch thick.

GOYA.

This cheese is manufactured in the Province of Corrientes, in the Argentine Republic. Either whole or partly skimmed milk is used. It is heated to a temperature of 75° to 85° F. and coagulated with rennet in 15 to 30 minutes. The curd is cut and put into sacks to drain, after which it is put into molds.

GRANULAR CURD.

This cheese resembles the genuine Cheddar process cheese in all points excepting that it is not matted and milled. As soon as the curd is cooked firm enough it is salted and pressed. Because no acid is developed between cooking and pressing, a little more acid may be allowed to develop before drawing the whey, and the curd should be cooked firmer.

GRAY.

This is a sour skim-milk product of the Tyrol. When the milk is thickened the curd is brought to a proper firmness by light heating, and is then dipped into a cheese cloth, care being taken that the flocculent matter at the bottom of the kettle is thoroughly mixed with the rest of the curd in order to insure an even product. The curd is put under a press for 10 minutes, when it is broken up by hand or in a mill and salt and pepper are added. The curd is then put into forms or hoops, and to insure the proper ripening a little well-ripened grated gray cheese is added, or bread crumbs with the characteristic mold growth are mixed with the curd as it is put into the forms. The forms are made in various shapes and sizes and are supplied with holes to facilitate drainage. The cheese remains in the forms under pressure for 24 hours, and is then taken to the drying room, which has a temperature of 70° F. The length of time it should remain in the drying room is determined by the appearance of the cheese. It is then taken to the ripening cellar. The cheese when ripened has a pleasant taste and a gray appearance through the entire mass.

GRUYÈRE.

This name is applied to Emmental cheese manufactured in France, the name originating from the Swiss village of Gruyère. The cheese was first mentioned in 1722, when two societies were reported to have been organized for its manufacture. The Gruyère cheese is made in three different qualities—whole milk, partly skimmed, and skimmed. It is usually made from partly skimmed milk, and this is supposed to distinguish it from Emmental, which is supposed to be made from whole milk. The manufacture of Gruyère cheese is an extensive industry in France, about 50,000,000 pounds having been manufactured annually the latter part of the last century.

GÜSSING.

This is an Austrian skim-milk cheese weighing from 4 to 8 pounds. It resembles very much the Brick cheese of the United States and is made in practically the same way.

HAND.

Hand cheese is so named because it was molded originally into its final shape by hand. It is a sour-milk cheese, very popular among German races, and manufactured in many countries.

The process of making varies in different localities, but in general is about as follows: The skimmed milk is mixed with buttermilk and put into a tinned vessel, where it is held at a favorable temperature for souring. When thick the curd is broken up by stirring and heated to 120° F. The cooking is continued for about 3 hours and for the first hour of this time is stirred thoroughly. After cooking, the whey is drained off and the curd is put in a mold for cooling. It is then ground fine in a curd mill and salt is incorporated, and for some kinds caraway seed is added. The curd is then pressed into the desired shapes and sizes. The small cheeses are dried in a warm room and then transferred to the curing cellar, where they are kept on shelves until the ripening on the surface has commenced, when they are packed in boxes. The cheese has a very sharp, pungent odor and taste, which to most people unaccustomed to it is very disagreeable.

There are many local names for hand cheeses, among which are the following: Thuringia caraway cheese; Ihlefeld, made in Mecklenburg; Livlander, made in Russia; Olmützer Bierkäse; Dresdener Bierkäse; Satz, made in Saxony; Tyrol sour cheese; Berliner Kuhkäse; and Alt Kuhkäse.

HARZ.

This is a hand cheese made in different sizes. It is 1½ to 2½ inches in diameter and one-fourth to three-fourths inch in thickness and weighs one-fourth pound. It is identical in manufacture with hand cheese.

HAY.

This cheese, known as Fromage de Foin, is a skim-milk variety made in the Department of Seine-Inférieure, France. The cheese derives its name from the fact that it is ripened on as freshly cut hay as possible, which gives a characteristic aroma to the cheese. The cheese in some respects resembles a poor grade of Livarot. It is about 10 inches in diameter and 2 to 3 inches thick.

The milk is set with rennet at a temperature of 80° to 85° F. In about 1 hour the curd is cut and the whey removed; the curd is then pressed to remove as much of the whey as possible, after which it is pressed by hand into molds. After draining for about 2 days it is put into the drying room, where it remains for about 3 weeks, when it is taken to the curing cellar and buried in hay. After remaining here for 6 weeks to 3 months it is ready for sale. The consumption of this variety is largely restricted to the region where it is made.

HOHENHEIM.

This is a soft cheese made in Hohenheim from partly skimmed milk. It is cylindrical in shape, 4 to 6 inches in diameter, and weighs about one-half pound.

The skimmed evening's milk is added to the morning's milk and heated in a copper kettle to 110° F. Some saffron is used for color and rennet is added. In 1 to 1½ hours the curd is broken up and the whey dipped off. Caraway seed is stirred in, by which process the curd is reduced to smaller particles. It is then dipped into tin hoops having holes to allow easy draining. The curd remains in these hoops for 12 hours and an additional 12 hours on a drying board. It is then sprinkled with salt and when this is dissolved it is again salted and placed in the ripening cellar. Ripening requires 3 months.

HOLSTEIN HEALTH.

This is a cooked cheese made from sour skimmed milk, the local name being Holsteiner Gesundheits Käse. The milk is heated lightly and the curd is strongly pressed; it is then well mixed and put in a tin kettle. A little cream and salt are added and the whole is stirred while it is being heated to the melting temperature over a fire. It is then put into a hoop or mold which holds about one-half pound and is allowed to cool.

HOLSTEIN SKIM-MILK.

As the name indicates, this is a skim-milk cheese made in the Province of Holstein, where it is known as Holsteiner Magerkäse. Usually in the manufacture of this cheese 6 per cent of buttermilk is added to separator skim milk. A part is heated to 160° F. and the remainder is mixed with the pasteurized portion. The milk is colored with saffron, and rennet powder is used for coagulating the casein, which requires about 35 minutes. The curd is then broken up and allowed to remain in the whey for 30 minutes without stirring. A cloth is then used for lifting the curd from the whey, and 1 per cent of salt is mixed in. The curd is pressed for one-half hour, when it is turned and pressure again applied. The pressure is gradually increased from 5 pounds to 9 pounds for each pound of cheese. The cheese is transferred to the curing cellar, which has a temperature of 60°. It is here turned daily until ripened, which requires 4 months. Each cheese weighs from 12 to 14 pounds.

HOP.

Hop or Hopfen cheese is a German product. The ground curd is salted and allowed to ripen for 3 or 4 days, when it is mixed with fresh curd and molded into small cheeses measuring about 2½ inches in diameter and 1 inch in thickness. These are placed in a well-ventilated room and allowed to become quite dry, when they are packed in hops.

HVID GJEDEOST.

This is a goat's-milk cheese made in Norway. The milk is set at 70° F. or higher. The curd is broken up and is cooked in the usual manner. It is then pressed in forms 9 to 10 inches long, 6 inches broad, and 4 inches high. The cheese is made only for local consumption.

ILHA.

Ilha is a Portuguese word meaning island, and is applied to the cow's milk cheeses made in the Azore Islands and imported quite extensively into Portugal. They are moderately firm cheeses measuring 10 to 12 inches in diameter and about 4 inches in thickness.

INCANESTRATO.

This name is applied to cheese made in Sicily. The mixture of evening's and morning's milk is curdled with rennet in about three-fourths of an hour. The curd is then stirred thoroughly and 2 per cent of water is added. After standing for 5 minutes the curd is separated from the whey, pressed by hand, and sometimes allowed to ferment for 2 to 3 days, when it is cooked in whey and then pressed and salted. Various spices are added. A kind known as Majocchino and made in the region of Messina, out of cow's, goat's, and sheep's milk, contains olive oil.

ISIGNY.

This is an American cheese originating about 30 years ago in attempts to make Camembert cheese in this country. The proper ripening for Camembert cheese was not secured and hence a distinct name was given to the product. The cheese is slightly larger than Camembert but of the same shape. The ripened product bears a close resemblance to Limburg. The process of manufacture is similar to that of Camembert. During ripening, however, the cheese is washed and rubbed occasionally to check the growth of molds on the surface.

JACK.

Jack cheese was first made in Monterey County, Cal., about 25 years ago and was first called Monterey cheese. Its manufacture under this name is still limited to that State, but its method of manufacture agrees closely with the granular curd method for Cheddar cheese. Morning's and evening's milk is mixed and warmed in a vat from 86° to 88° F. and rennet extract added at the rate of 6 to 8 ounces per 1,000 pounds of milk. No coloring matter is used. It is ready for the curd knife in about half an hour, its readiness being determined as in Cheddar cheese. The cutting is done with a curd knife, the product then being stirred by hand and by rake. The curd is heated from 98° in winter to 105° to 110° in summer. After the temperature is up it is stirred occasionally with the rake until the whey is drawn at 0.14 to 0.15 per cent acidity. The curd is then stirred thoroughly to keep from matting and is salted at the rate of 1½ pounds to 100 pounds of curd, the whole being thoroughly stirred. During the salting process cold water is run under the vat, the hot water having been previously run off.

The curd is put into press cloths at a temperature of 80° to 85° F., no hoops being used. One gallon of curd is put into each cloth, making a cheese weighing 6½ pounds. The corners of the cloth are caught up tight, the cheese being pressed and rolled with the other hand. These are then pressed over night and placed in the curing rooms for 3 weeks before being ready to ship.

JOCHBERG.

This cheese is made from a mixture of cow's and goat's milk in the Tyrol. The cheese weighs 45 pounds and is 20 inches in diameter and 4 inches high.

JOSEPHINE.

This is a soft cured rennet cheese made from whole cow's milk in Silesia. It is put up in small cylindrical packages.

KAJMAK.

The Turkish word Kajmak signifies cream and is used to designate a product made in Servia and sometimes known as Servian butter. This product is, however, analogous to a cream cheese. The milk is boiled and put into large shallow vessels usually made of wood, and allowed to stand for 12 hours, when the cream is removed and usually salted. The flavor varies greatly with the age of the sample and is said to be between that of a goat's-milk cheese and Roquefort.

KASCAVAL.

This is a loaf-shaped rennet cheese weighing from 4 to 6 pounds, made from sheep's milk in Bulgaria, Roumania, and Transylvania. Goat's milk is sometimes added. Considerable quantities of the cheese are exported.

KATSCHKAWALJ.

This is a sheep's milk cheese made in Servia. The milk is curdled with rennet and the curd is drained and inclosed in tin cans which are put into boiling water. The curd is subsequently worked by hand and molded into various shapes. A cheese weighs ordinarily about 6 pounds.

KJARSGAARD.

This is a hard rennet cheese made in Denmark from skimmed cow's milk.

KLOSTER.

This is a soft ripened rennet cheese made from unskimmed cow's milk. It has a somewhat unusual shape, 1 by 1 by 4 inches, and weighs less than one-fourth pound.

KOLOS-MONOSTOR.

This is a sheep's-milk rennet cheese made in the agricultural school in Transylvania. The cheese is rectangular in shape, 8½ by 5 by 3 inches, and weighs 4 pounds.

KOPPEN.

Koppenkäse is a goat's-milk cheese made in Germany. The milk is set at 80° to 85° F., and after the whey has been dipped off the curd is put into a cup-shaped vessel which gives form to the cheese and also the name. The cheese is placed in a warm room and sprinkled with salt. It is allowed to dry for from 2 to 3 days and is then placed in the ripening room. The ripened cheese weighs from 3 to 4 ounces. It has a sharp, pungent, slightly smoky flavor.

KOSHER.

This cheese under various names is made in several countries. It is a cow's-milk rennet cheese made for the Jewish trade. The process of manufacture resembles that of Limburg. The cheese, however, is eaten fresh.

KOSHER GOUDA.

This is a cheese made especially for the Jewish trade. It is identical with a Gouda cheese in every way except in size and in having no bladder covering. It weighs from 4 to 6 pounds and is 8½ inches in diameter and 3 inches thick. It bears a stamp which identifies it to the Jewish consumer. Small quantities are imported into this country.

KRUTT.

Krutt, or Kirgischerkäse, is made by the nomadic tribes of the middle Asiatic Steppes from sour skim milk of the cow, goat, sheep, or camel. When the milk coagulates salt is added and the curd is hung up in a sack to drain, after which it is subjected to moderate pressure. The curd is then made up into small balls which are placed in the sun to dry.

KUHBACH.

This is a soft ripened rennet cheese made from whole or partly skimmed cow's milk. It is a German product, made in upper Bavaria. It is cylindrical in shape, weighs 2 pounds, and is 6 inches in diameter and 3 inches high.

LAGUIOLE.

This is a hard rennet cheese varying but little if any from Cantal and resembling Roquefort. It derives its name from the village of Laguiole in the Department of Aveyron, France. The cheese is made extensively in the mountains of Aubrac, where it is said to have been made at the time of the Roman occupation. The milk, either whole or partly skimmed, is set with rennet, the time allowed being about 30 minutes. The curd is allowed to ferment for about 24 hours and is then put into hoops and pressed. At least 1 month is required for ripening. Laguiole or Guiole cheese is considered superior to Cantal, although the two varieties are made in essentially the same way.

LANCASHIRE.

This is an English cheese named from the county in which it is made. The evening's milk is partly skimmed and is heated, so that when the morning's milk is added the temperature of the whole is brought to 80° F., or slightly higher. Enough rennet is added to coagulate the milk in 1 hour. The curd is broken up, stirred for a short time, and pressed on the bottom of the vat by means of a heavy sieve. The whey is soon drained off and the curd is ground in a curd mill into particles the size of kernels of corn and then put into the press. Salting is done in brine, in which the cheese is placed for 4 to 6 days. From the brine tank the cheese is transferred to the curing room.

LANGRES.

This is a soft rennet cheese made in the northeastern part of France. It derives its name from the village of Langres in the Department of Haute-Marne, where it is said to have been made since the time of the Merovingian kings. The perfectly fresh milk is set with rennet at a temperature of about 90° to 95° F. After standing for several hours it is put into cylindrical forms. The cheeses ripen for about 2 to 3 months. A ripened cheese weighs from 1½ to 2 pounds and is about 5 inches in diameter and 8 inches high. The cheese is consumed for the most part in the region where made.

LAPLAND.

The Laplanders make a variety of cheese from the milk of the reindeer. It resembles very much the harder varieties of the Emmental group. The cheese has a very unusual shape. It is round and flat and is so formed that a cross section would resemble a dumbbell with angular instead of round ends.

LATTICINI.

This is applied to cheeses made from the milk of buffaloes, particularly in the region of Naples, but also in other parts of Italy.

LEATHER.

Leather, Leder, or Holstein dairy cheese is made in Schleswig-Holstein, from skimmed cow's milk with an addition of from 5 to 10 per cent of buttermilk.

The milk is set at from 95° to 100° F. and requires 25 to 35 minutes for coagulation. It is then broken up with a harp or a stirring stick, and is stirred with a Danish stirrer. When the particles are reduced to the size of peas the curd is piled up on one side of the vat or kettle and allowed to stand for 10 minutes. The whey is then dipped off. The curd is cut with a knife into pieces the size of the hand, put in a wooden or tin bowl, and pressed for one-half hour, when it is cut into pieces and run through a cheese mill. It is then salted, put in a cloth, and again put in the press, where the pressure is gradually increased. The cheese is turned occasionally and a fresh dry cloth supplied. After 12 hours of pressing the cheese is put into the salt bath, where it is kept 40 to 48 hours. It is then transferred to the ripening cellar, where it is wiped with a dry cloth every day for about a week and thereafter twice a week, the ripening requiring about 4 months. The cured cheese has small eyes; it is made cylindrical, and is 4 to 6 inches in height and 10 to 12 inches in diameter. It weighs 15 to 25 pounds.

LEICESTER.

This is a hard rennet cheese made from whole cow's milk. It is named from a county in England where it is made. It resembles the better known Cheshire and Cheddar in every way.

Evening's and morning's milk are mixed and set at a temperature of from 76° to 84° F. The curd is allowed to set very firm, which requires 90 minutes. It is cut very carefully and allowed to settle 20 minutes, when the whey is drawn off. The curd is then gathered in a cloth, pressed, and broken up several times until a certain degree of dryness has been attained, and then salted lightly and put to press. Pressure is continued for 5 days, the cheese being removed and salted on the outside each day.

LEYDEN.

This is a hard rennet cheese made in Holland, where it is known also as Bergues, Delft, Komynde, Koejekaars, and Hobbe. The milk, which is either partly or entirely skimmed, is set with rennet at 72° to 75° F. It is allowed to stand for 1 hour, when the curd is cut and then stirred while being warmed up to 97°. The heating is done by pouring hot whey over the curd. The curd is then dipped out with a cloth and kneaded by hand. Caraway seed is added to a portion of the curd which, in filling the hoops, constitutes the middle of three layers. The cheese is then put in press. It is turned after 3 hours and a fresh cloth applied. The pressing continues for 24 hours. Salting is done on the surface daily. If the rind becomes hard it is washed in whey or water, and occasionally milk is smeared on the surface. The surface is colored with litmus in alkaline water. A ripened cheese weighs about 25 pounds and is 12 inches in diameter and 3½ to 5 inches in thickness. As seen on the American market, it has a very dark-brown surface.

LIMBURG.

This is a soft rennet cheese made from cow's milk which may contain all of the fat or be partly or entirely skimmed. The best Limburg is undoubtedly made from whole milk. This cheese has a very strong and characteristic odor and taste. The cheese is about 6 by 6 by 3 inches and weighs about 2 pounds.

The most common synonyms of Limburg are Backstein and Hervé. There are, however, many local names for this kind of cheese, such as Algau, Lanark, Marianhof, Morin, St. Michels, Schützen, Tanzenberg, Carinthian, Grottenhof, Emmersdorf, Briol, and Lindenhof.

Limburg cheese originated in the Province of Lüttich, Belgium, in the neighborhood of Hervé, and was marketed in Limburg, Belgium. Its manufacture has spread to Germany and Austria, where it is very popular, and to the United States, where large quantities are made, mostly in New York and Wisconsin.

Sweet milk is set without any coloring matter at a temperature of from 91° to 96° F. with sufficient rennet to coagulate the milk in about 40 minutes. In foreign countries a kettle is used, but in the United States an ordinary rectangular cheese vat is found to be more satisfactory. The curd is cut or broken into pieces about one-third-inch cube and is stirred for a short time without additional heating. It is then dipped into rectangular forms 28 inches long, 5½ inches broad, and about 8 inches deep. These forms are kept on a draining board, where the whey drains out freely. When the cheese has been in the forms, with frequent turnings, for a sufficient length of time to retain its shape it is removed to the salting table, where the surface is rubbed with salt daily. When the surface of the cheese commences to get slippery, the cheese is put in a ripening cellar having a temperature of about 60°. While in the cellar the surface of each cheese is rubbed thoroughly at frequent intervals. Ripening requires 1 to 2 months. When ripe the cheese is wrapped in paper, and then in tin foil, and put in boxes, each containing about 50 cheeses.

No Limburg is imported into this country at the present time, contrary to the popular belief. This type of cheese is made so cheaply and of such good quality in this country that the foreign make has been crowded out of the market.

LIPTAU.

This cheese is made in the Provinces of Liptau, Saros, and Arva, in Hungary, from sheep's milk. Condiments, especially red pepper, are usually added. It is rather greasy and has a sharp taste. The details of manufacture are the same as for Brinsen cheese.

LIVAROT.

This is a soft rennet cheese made from cow's milk more or less skimmed. It derives its name from the village of Livarot in the Department of Calvados, France, where the industry is centralized. This cheese has the advantage over Camembert made in the same region in that it may be manufactured and consumed during the warm months.

The milk is set with rennet at a temperature of 95° to 104° F. After 1½ to 2 hours the curd is cut and placed on a rush mat or a cloth and allowed to drain for about 15 minutes, during which time it is crumbled as finely as possible. It is then put into tin hoops or forms 6 inches in diameter and the same in height. The cheeses are turned very frequently until they become firm, when they are salted and left on the draining board for 4 or 5 days. At this stage they are sometimes sold as white cheese, but more often they are transferred to a well-ventilated room for 15 to 20 days and then to the curing cellar, which is kept very tightly closed. By thus retaining the ammonia and other products the cheese acquires a strong, piquant taste. During ripening the cheeses are turned two or three times a week and occasionally wiped with a cloth moistened with salt water. After ripening for 10 to 12 days they are wrapped with the leaves of *Typha latifolia*, commonly called laiche. In 3 to 5 months they are colored with annatto and marketed.

LORRAINE.

This is a small sour-milk hand cheese made in Lorraine, Germany, and regarded as a delicacy in that country. It is seasoned with pepper, salt, and pistachio nuts, and is eaten in a comparatively fresh state. The cheeses are made in sizes of about 2 ounces and sell for a very high price—at the rate of about 50 cents a pound.

LÜNEBERG.

This cheese is made in the small valleys of the Voralberg Mountains in the western part of Austria. The art of cheese making in this locality was imported from Switzerland, and the copper kettle and characteristic presses are used. Saffron is used for coloring, and the milk is warmed in the copper kettle to 87° to 90° F., at which temperature the rennet is added, enough being used to coagulate the milk in 20 to 30 minutes. The curd is cut into pieces the size of hazelnuts and is cooked with stirring to a temperature of 122°. The curd is dipped into cloths which are put into wooden forms and light pressure is applied. The curd remains in the press for 24 hours, during which time it is turned occasionally and a dry cloth supplied. The cheese is then taken to the cellar and is salted on the surface. In the cellar it is rubbed and washed occasionally. When ripe it is said to be about midway in type between Emmental and Limburg.

MACONNAIS.

This is a French goat's-milk cheese, 2 inches square by 1½ inches thick.

MACQUELINE.

This is a soft rennet cheese of the Camembert type, 4 inches in diameter and 1½ inches thick, made from whole or partly skimmed milk in the region of Senlis, in the Department of Oise, France. The milk is set with rennet at a temperature of about 80° F. and allowed to stand for 5 hours, when the curd is put into hoops. After 24 hours the hoops are removed and the cheese is salted and taken to the curing room, where it remains for 20 days or more. A cheese weighs about one-fourth of a pound and requires about 2 liters of milk in its manufacture. The cheese sells at a lower price than Camembert, made in the same region.

MAIKÄSE.

This is a cheese resembling Gouda. It is made in Holland in the early summer, is softer than the regular Gouda, and hence can be marketed at an earlier period.

MAINZ HAND.

This is a typical hand cheese, sometimes called Pimp. The milk is treated in the usual way, and the curd after cooling is thoroughly kneaded by hand, the thoroughness of this manipulation influencing the quality of the cheese. The curd is then pressed by hand into flat cakes and allowed to dry for a week. They are then packed in a jar or keg and placed in a cellar for ripening. This requires from 6 to 8 weeks.

MALAKOFF.

This is another form of Neufchâtel cheese about 2 inches in diameter and one-half of an inch in thickness. It may be consumed either while fresh or after ripening.

MANUR.

This cheese is made in Servia from either sheep's or cow's milk. The milk is first heated to the boiling temperature and then cooled until the fingers can be held in it. A mixture of buttermilk and fresh whey with rennet is added. The curd is lifted from the whey in a cloth and allowed to drain, when it is kneaded like bread, lightly salted, and dried.

MAQUÉE.

This is a soft rennet brick-shaped cheese made from cow's milk in Belgium. It is known where made as Fromage Mou.

MÄRKISCH HAND.

This cheese is similar to a hand cheese. The milk is treated in the same way as in hand cheese up to the salting. The curd is then put in a linen sack and heavy pressure is applied. The mass is then cut into oblong pieces and allowed to dry and cure as regular hand cheese.

MAROILLES.

This is a soft rennet cheese of the Pont l'Évêque type made from whole or partly skimmed cow's milk in the Departments of Aisne and Nord, France. There are several kinds, varying in size, shape, and details of manufacture, of which the Tuile de Flandre and Larron are best known. The cheese as made at Maroilles is about 6 inches square and 2 inches thick; that made at Saint Aubin, 5 inches square and 3 inches thick. The Larron is about 2½ inches square and 1½ inches thick, and weighs about 6 ounces. The Tuile de Flandre is about twice as large. The Dauphin is semilunar in shape and contains herbs. A pear-shaped form designated Boulette may be made in part from buttermilk.

The best cheese is made from fresh whole milk, although the most of it is made from milk partly or entirely skimmed. The temperature of setting with rennet is about 75° F. and the time allowed from 1 to 4 hours. The curd is drained for 1 to 2 hours in a box having a perforated bottom, and is then put into square forms or hoops 5 to 6 inches on a side and 3 to 4 inches high. The cheese is turned frequently until firm and then salted on all six faces and taken to the curing cellar, where it is washed frequently with salt water to prevent the growth of molds. Ripening requires 3 to 5 months. Defective cheeses are said to be common.

MASCARPONE.

This is an Italian cream cheese about 2 inches in diameter and 2½ inches in height. The cream is heated to about 194° F. and dilute acetic or tartaric acid is added. The mixture is stirred and drained through cloth and then put into molds. It is eaten in a fresh condition.

MECKLENBURG SKIM.

This is a rennet cheese made from skim milk and named from the province in which it is made. The milk is placed in a copper kettle and warmed with steam. Saffron is added for coloring and sufficient rennet is used to coagulate the milk in 30 minutes. The curd is broken up into particles the size of peas. The temperature is raised to 92° F. in 12 minutes. The curd is then removed from the kettle by means of a cloth and put into a hoop and pressure applied. This is increased gradually until it reaches fifteen times the weight of the cheese in 24 hours. The cheese is then placed in a drying room held at 70° until a rind is formed. As much salt is then sprinkled on the surface as can be absorbed. In the meanwhile the cheese is taken from the drying room and placed in the regular curing room, which has a temperature of 60° and a relative humidity of 85 to 95 per cent.

MIGNOT.

This is a soft rennet cheese either cylindrical or cubical in form. It has been made in the Department of Calvados, France, for over 100 years and resembles Pont l'Évêque and Livarot. There are two types of this cheese; designated white and passé; the first, a fresh cheese, is made during the period from April to September, and the second, a ripened cheese, is made during the remainder of the year.

MONTASIO.

This cheese originated in the part of Carinthia, in Austria, called Friaul, where the annual product is now valued at $600,000. At the present time it is made not only in Carinthia but in the neighboring provinces and in Italy.

The milk, either whole or partly skimmed, and consisting usually of a mixture of cow's and goat's milk, is heated in a kettle to 95° F. and sufficient rennet is added to coagulate it in 30 to 40 minutes. It is then cut very carefully to the size of peas and heated gradually to a temperature of 120°. When the desired temperature is reached, which is usually in about one-half hour, heating is stopped and the stirring continued for 30 to 40 minutes. Some of the whey is dipped from the kettle and the curd is removed by means of a cloth. The cheese is pressed for 24 hours, during which time it is turned frequently. The salting requires usually about one month, the total amount applied varying from 2½ to 3 per cent of the weight of the pressed cheese. After salting, the cheese is taken to a well-ventilated room and allowed to dry. In this room the cheese is turned frequently and rubbed in order to free it from molds. When dry it is scraped carefully and taken to the curing cellar. The cheese is here rubbed frequently with a coarse cloth, and when the rind has become firm and does not show the presence of mold, olive oil is usually applied. Sometimes the rind is colored black by means of soot.

The fresh cheese is almost white. The old cheese becomes yellow, granular, and has a sharp taste and characteristic odor. It is usually eaten when 3 to 12 months of age, but may be kept much longer and then grated.

MONTAVONER.

This is a sour-milk cheese made in Austria. During the process of manufacture dried herbs (*Achillea moschata* and *A. atrata*) are added.

MONT CENIS.

This is a hard rennet cheese resembling the imitation Roquefort varieties like Gex and Septmoncel and made in the region of Mont Cenis, in the southeastern part of France. The milk used is usually a mixture of cow's, sheep's, and goat's. The evening's milk is usually skimmed and added to that of the morning. Primitive methods of cheese making are employed. The milk is set with rennet at a temperature of about 85° F. The curd is then cut and allowed to drain for 24 hours, when fresh curd is thoroughly mixed with it. The mixture is then put into molds and moderate pressure applied. After turning frequently for several days, and salting, it is transferred to the curing cellar, where it is turned frequently, washed with salt water to check the growth of molds on the surface, and allowed to ripen for 3 to 4 months. The ripening is due mainly to a penicillium which is sometimes incorporated in the curd by means of moldy bread. A ripened cheese is about 18 inches in diameter, 6 to 8 inches in height, and weighs about 25 pounds.

MONT D'OR.

This is a soft rennet cheese of the Pont l'Évêque type, formerly made from goat's milk but now made almost exclusively from cow's milk. Sometimes a small amount of goat's milk is added to the cow's milk.

It derives its name from Mont d'Or, near Lyon, in the Department of Rhône, France, where it is said to have been made for over three centuries At the present time it is made not only in Rhône and neighboring Departments but in the other parts of France, especially Eure and Oise.

Whole or partly skimmed milk is set with rennet at a temperature of 90° to 100° F. The curd, in from one-half hour to 2 hours after the addition of the rennet to the milk and with or without cutting, is put into circular forms or hoops about 4½ inches in diameter and 3 inches high. These rest upon a draining board covered with straw. After about 1 hour the cheese is turned, and frequently thereafter until firm. A disk with a light weight is sometimes placed upon each cheese in order to hasten the removal of the whey. The cheese is salted on the surface. Much of it is sold in a fresh condition. It is also ripened for about one week in summer and 2 to 3 weeks in winter, during which time it is turned frequently and washed with salt water to prevent the growth of molds.

MONTHLÉRY.

This is a soft rennet cheese made from cow's milk in Seine-et-Oise, France. A large cheese is about 2 inches thick and 14 inches in diameter and weighs about 5½ pounds. There is also a smaller sized cheese which weighs about 3 pounds. Either whole milk or partly skimmed milk is used. Rennet is added to the milk at ordinary temperatures, and the curd when sufficiently firm is broken up, put into molds, and subjected to pressure. After salting the cheese is cured for 8 to 15 days in a so-called drying room and then ripened in a cellar at a temperature of about 55° F. During ripening the cheese becomes covered at first with a whitish mold and later with a blue mold in which red spots appear. It is ready for sale at the end of about 1 month.

MOZARINELLI.

This is a soft rennet cheese made from cow's milk in Italy.

MÜNSTER.

Münster is a rennet cheese made from unskimmed cow's milk in the western part of Germany, near the Vosges Mountains, and named from the city of Münster, near which it is made. Similar cheese made in the neighboring portion of France is called Géromé, and Münster cheese made near Colmar and Strassburg is sometimes given the names of these two cities.

The milk is set at about 90° F. with sufficient rennet to coagulate it in 30 minutes. The curd is then broken up and allowed to stand for 30 to 45 minutes without stirring, when it is dipped with a sieve which holds back the small particles of curd and gives a slight pressure to the curd. After removing the whey the curd is scooped into forms or hoops and caraway or anise seed is usually added. The hoops are made in two parts, the lower of which is 4 inches high and 7 inches in diameter with holes in the bottom for draining, and the upper of which is of the same dimensions. The whole resembles an ordinary cheese hoop with bandages. The hoop is lined with cheese cloth. After the curd has been in the hoop for 12 hours the upper part of the hoop can be removed. The cheese is turned and the cloth removed. The cheese is now put in the upper portion of the hoop and turned frequently for 4 to 6 days. The temperature is held in the meanwhile at 68°. After salt has been rubbed on the surface daily for 3 days the cheese is taken to the cellar, which has a temperature of 51° to 55°, where it is allowed to ripen for 2 to 3 months. The cheese sells for about 15 cents a pound when ripe.

MYSOST.

Mysost is made from whey and is a product of Norway, Sweden, and Denmark, and to a very limited extent of the United States. It has a light-brown color, a buttery consistency, and a mild, sweetish taste.

The method of manufacture is as follows: As soon as the curd of the regular cheese is removed from the whey, the whey is strained and is put in a kettle or large pan over the fire and the albuminous material which rises to the surface is skimmed off. The whey is evaporated as rapidly as possible with constant and thorough stirring. When it has reached about one-fourth its original volume the albumin previously skimmed off is returned and stirred thoroughly to break up all possible lumps. When the whey has attained the consistency of thickened milk it is poured quickly into a wooden trough and stirred with a paddle until cool to prevent the formation of sugar crystals. This can then be molded into the desired form. In this country it is usually made into cylindrical shapes and wrapped in tin foil. Prumost is a local name for this cheese.

NESSEL.

This is a soft-cured rennet cheese made from unskimmed cow's milk. It is an English product and is made round and very thin.

NEUFCHÂTEL.

This is a soft rennet cheese made extensively in the Department of Seine-Inférieure, France, from cow's milk either whole or skimmed. Bondon, Malakoff, Petit Carré, and Petit Suisse are essentially the same as Neufchâtel, but have slightly different shapes.

The milk, preferably fresh, is set at 85° F. with only so much rennet as is necessary to secure the desired coagulation in 24 hours in summer and from 36 to 48 hours in winter. The curd is then inclosed in cheese cloth and drained for 12 hours, after which it is subjected to pressure for another period of 12 hours. It is then thoroughly kneaded by hand or, in the larger factories, by means of a curd mill and pressed into thin cylinders about 2 inches in diameter and 3 inches high. The cheeses are removed soon from the molds, salted, and replaced. After draining for 24 hours they are transferred to the so-called drying room, where they become covered with white and later with blue molds. They are then taken to the curing cellar, where the ripening process is continued for 3 to 4 weeks. The appearance of red spots on the surface is taken as an indication that the ripening has progressed far enough. The cheeses are then wrapped in tin foil and marketed.

An imitation of the Neufchâtel cheese is made in the United States which is very probably as good as the French variety. Makers in this country have attempted to vary this cheese by the use of condiments. Pimento, or Pepper Cream, is a Neufchâtel cheese in which 1 pound of red peppers is used for every 10 pounds of cheese. The peppers are ground very fine and thoroughly mixed with the cheese; the whole is then molded into forms and kept in a cold place.

NEW MILK.

This cheese is made in Holland. The process of manufacture resembles that of Gouda cheese. It is made only in limited quantities at the beginning of the summer season and is eaten fresh.

NIEHEIM.

This is a sour-milk cheese made in Westphalia and named from a city in that province. The sour milk is heated to a temperature of 100° to 120° F. The curd is collected in a cloth and allowed to stand for 24 hours, when it is worked until in a fine condition. The curd is made up into cakes which are put into a cellar and turned frequently for 5 to 8 days. It is then broken up, and salt and caraway seed, and sometimes beer or milk, are added. The cheese is covered lightly with straw and finally packed in casks with hops and allowed to ripen.

NOSTRALE.

This name is applied locally to two kinds of rennet cheese made from cow's milk in the mountainous regions of northwestern Italy. The hard cheese, designated Formaggio Duro, is made during the spring while the herds are still in the valleys, and the soft cheese, Formaggio Tenero, during the summer when they are pastured in the mountains. The cheese is said to be a very old variety and the methods of manufacture to have remained primitive. A cheese designated Raschera, made in the region of Mondovi, is probably the same as Nostrale.

OLIVET.

This is a soft rennet cheese made from cow's milk. The manufacture of this variety originated south of Orleans, in the Department of Loiret, France. The industry is now carried on north of Orleans near Olivet, to which place the cheese doubtless owes its name. There are three forms of this cheese, designated white or summer cheese, blue or the ordinary half-ripened form, and ripened. In general the process of manufacture resembles that of Camembert. The ordinary form is made from either whole milk or partly skimmed milk. About 2 hours after the addition of rennet the curd is placed in a receptacle having holes in the bottom and sides and allowed to drain for 24 hours, when it is put into forms about 6 inches in diameter. The cheese is turned and salted the next day, and about 1 day later is taken to the first curing room, where it is placed on shelves covered with straw. This room is kept at a temperature of about 65° F. Here the cheese becomes red in a few days and later blue. The blue color is a sign of maturity, and its appearance requires from 10 to 15 days in summer and 1 month in winter. The cheese is then ready for marketing. When properly cared for it may remain in good condition for several months. The form designated ripened is made in the same way until the blue color appears, when the cheese is put into the curing cellar, where ripening is carried to a much further extent. Ordinarily this requires from 15 to 30 days, but the cheese is here sometimes covered with ashes, which are believed to hasten the ripening process. The form designated white or summer cheese is made from whole milk, to which cream is sometimes added. The curd is obtained in the ordinary manner and pressed into molds, in which it is sold as fresh cheese, summer cheese, white cheese, or cream cheese.

OLMÜTZER QUARGEL.

This is a hand cheese made extensively in the western part of Austria. It is 1½ inches in diameter and one-third of an inch thick and contains caraway seed. It is made with 5 per cent of salt and after drying is put in salt whey for a time. It is then packed in kegs and ripened for 8 to 10 weeks. In all other respects the manufacture is identical with that of hand cheese.

PAGLIA.

This is a more or less successful imitation of Gorgonzola cheese, made in the Canton of Ticino, Switzerland. A cheese is 8 inches in diameter and 2 inches in thickness. The milk is set at a temperature of 100° F., the time allowed being about 15 minutes. The curd is broken up, stirred, and put into hoops. When sufficiently drained the cheese is taken to a cool cellar and placed on straw, where fermentation is usually very rapid and marked. The process is delayed to some extent by excessive salting, which is continued for about 1 month. The cheese is very soft in consistency and has a pleasant aromatic flavor.

PAGO.

This is a rennet cheese made from sheep's milk in the island of Pago, in the Province of Dalmatia, Austria. It is put up in sizes weighing from one-half to 8 pounds.

PARMESAN.

This name is in common use outside of Italy for the cheese made and known in that country for centuries as Grana, the term " grana " or " granona " referring to the granular appearance of the cheese when broken, as is necessary on account of the hardness of the cheese, which makes cutting practically impossible. There are two quite distinct kinds of this cheese, one made in Lombardy and the other in Emilia, the centers of production being separated by the River Po. Parma, situated in Emilia, has long been an important commercial center for both kinds, and to this fact the name Parmesan is due. The use of the term " Parmesan," however, is sometimes restricted to the cheese made in Lombardy, the term " Reggian " being used to designate that made in Emilia. Italian writers refer usually to the Lombardy cheese as Cacio or Formaggio Grana Lodigiano, Lodi being an important center of trade, and to the Emilian cheese as Grana Parmigiano or Reggiano. The Lodi cheese is larger and made from a poorer quality of milk than the Reggian. The latter is colored and brings a much higher price. The following description of the process of manufacture applies equally well to both kinds:

The milk, which has been skimmed to a greater or less extent, is heated in copper kettles to a temperature varying, according to the acidity of the milk, from 90° to 100° F. The kettle is then removed from the fire, rennet added, and the kettle covered and allowed to stand for 20 minutes to 1 hour, when the curd is cut very fine and cooked, with stirring, to 115° to 125° F. for 15 to 45 minutes. The curd is removed from the kettle by means of a cloth and after draining for a short time is put into hoops. These are about 10 inches high and 18 inches or more in diameter and are lined with coarse cloth before filling. Pressure is then applied for 24 hours, the cheese being turned frequently and the cloths changed. The salting, which is begun in 1 to 3 days after removing from the press, is continued for a considerable length of time, often 40 days. The cheeses are then transferred to a cool, well-ventilated room, where they may be stored for years, the surface being rubbed with oil from time to time. The exterior of the cheese is dark green or black, due to coloring matter rubbed on the surface. A greenish color in the interior has been attributed to the contamination with copper from the vessels in which the milk is allowed to stand before skimming.

The Lombardy cheese made from April to September is known locally as Sorte Maggenga and that from October to March as Sorte Vermenga. The Reggian cheese is made only in summer.

Parmesan cheese when well made may be broken and grated easily and may be kept for an indefinite number of years. It is grated and used largely for soups and with macaroni. A considerable quantity of this cheese is imported into this country and sells for a very high price.

PECORINO.

The Formaggio Pecorini are the sheep's-milk cheeses made in Italy and of which there are numerous more or less clearly defined kinds. The most common cheese of this sort is the one designated Cacio Pecorino Romano, or merely Romano. This varies considerably in size and shape. The weight may range from 2 to 25 pounds. A cheese of ordinary size is about 10 inches in diameter and 6 inches in thickness. The interior is slightly greenish in color, somewhat granular, and devoid of eyes or holes. In making Romano cheese the milk is heated to 100° F. and coagulated by rennet in 15 minutes. The curd is cut, cooked to 120°, stirred, and put into forms and allowed to drain. Salting is done both by immersion in brine and by rubbing salt on the surface. As much as 7 to 8 per cent of salt is usually incorporated in the course of one month. This process is sometimes facilitated by punching several holes in the cheese. Ripening is usually done at a temperature of 60° to 70° and requires 8 months or longer.

The Pecorino Dolce is artificially colored with annatto and subjected to considerable pressure in the process of manufacture.

Pecorino Tuscano is a smaller cheese than the Romano, measuring usually 6 inches in diameter and 2 to 4 inches in thickness and weighing 2 to 5 pounds.

Among the sheep's-milk cheeses bearing local names are the following: Ancona, Cotrone, Iglesias, Leonessa, Puglia, and Viterbo. In the manufacture of Viterbo cheese the milk is curdled by means of a wild artichoke, *Cynara scolymus*.

PFISTER.

This cheese is classed in the Emmental group, though its method of manufacture differs materially. It is made from fresh skimmed cow's milk. It takes its name from Pfister Huber, in Cham, Switzerland, who evidently was the first to manufacture it.

The milk is set at 85° F. with sufficient rennet to coagulate it in 30 minutes. The curd is cut coarse and allowed to stand for 15 minutes when the whey is dipped off. The curd is again stirred for 5 minutes, care being taken that the temperature does not fall below the setting point. The curd is again allowed to stand for 5 minutes, when it is taken from the kettle in a cloth and put in a hoop, where it is pressed for 24 hours, being turned occasionally and dry cloths substituted. The cheese is transferred from the press to the salt bath, where it remains for 3 days. It is then taken to a moist room having a temperature of 85°. Here it is placed on shelves and turned and salted occasionally. The cheese is ready for market at about 6 weeks of age. It is drum-shaped, like a characteristic Emmental, but not so large, weighing about 50 pounds.

PHILADELPHIA CREAM.

This is an ordinary cream cheese put up by a firm in New York State. It is 3 by 2½ by 1¼ inches in size and is wrapped in parchment paper and tin foil.

PINEAPPLE.

This cheese, which is said to have had its origin in Litchfield County, Conn., about 1845, is so named from the fruit of that name which the cheese is made to resemble in shape. It is a hard rennet cheese made from whole cow's milk. The cheese is quite hard and is rather highly colored. The early process of manufacture is the same as with Cheddar, except that it is cooked much harder. The curd is pressed in the desired shape in various sizes up to 6 pounds in weight. After pressing, the cheese is dipped for a few minutes in water at 120° F. and is then put in a net for 24 hours, which gives it the diamond-shaped corrugations on the surface. It requires several months to ripen, and during this time the surface is rubbed with oil, which makes it very smooth and hard.

PONT L'ÉVÊQUE.

This is a soft rennet cheese made from cow's milk. Three grades are recognized, depending upon the quality of the milk used. A Pont l'Évêque cheese is about 4½ inches square and 1¼ inches thick.

This cheese was made in the thirteenth century in the valley of Auge, from which it derived its earlier name Augelot, and by corruption Angelot. The principal seat of the industry at the present time is Pont l'Évêque and vicinity, in the Department of Calvados, France. The manufacture of this cheese is of considerable importance in the region designated. The milk used may be either whole milk with or without the addition of cream, a mixture of whole and skimmed milk, or milk entirely skimmed.

Coloring matter and warm or hot water are usually added to the milk before setting with rennet, which is done at a temperature of about 95° F. After standing for 15 to 30 minutes the curd is cut, removed to a draining board for a few minutes, and then put into square forms or hoops. The cheese is turned very frequently during the first half hour and five or six times more during the remainder of the first day. It is salted the second or third day and transferred to a well-ventilated room for several days. When sufficiently dried it is taken to the curing cellar. During drying and ripening the cheeses are turned every day and while in the cellar are washed frequently with salt water. Ripening requires usually from 3 to 6 weeks.

PORT DU SALUT.

This is a rennet cheese made from cow's milk. In many respects it is intermediate between the soft and hard varieties. The rind is firm and resistant but the interior is soft and homogenous, though it does not become semiliquid like the interior of Brie cheese. This variety of cheese originated about 1865 in the Trappist Abbey, Port du Salut, situated about 6 miles from Laval, in the Department of Mayenne, France. While the process is to some extent kept a secret by the Trappists, very successful imitations are made outside of the monasteries in this region.

The milk, either whole or partly skimmed and preferably slightly acid, is heated to 90° to 95° F. and sufficient rennet added in order to secure the desired firmness of the curd in about 30 minutes. Coloring matter is usually added to the milk. The curd is cut very fine and in a manner similar to that followed in making Emmental cheese. This requires about 20 minutes. A part of the whey may then be removed. The curd is then stirred and may be heated or cooked to a moderate degree. The final temperature reached in cooking varies from 100° to 105°, depending upon the acidity of the milk. The time required in stirring and heating is about 20 minutes. The curd is then allowed to settle and the whey removed. After being stirred vigorously for two to four minutes, the curd is put into molds which are of two sizes, the smaller about 7 inches in diameter and the larger about 10 inches. A disk is placed on the cheese and pressure applied by means of presses for 10 to 12 hours, the cheese being turned and the cloths frequently changed during this time. The next day the hoops are removed and the cheese salted. After drying for about 24 hours, it is transferred to the ripening cellar, where it remains from 5 to 6 weeks. In this place a temperature of about 55° and a relative humidity of 85° to 90° is preferred. During ripening the cheeses are turned very frequently and washed with salt water, the frequency depending somewhat upon the rapidity with which molds develop. The cheese is often sold before the ripening process is entirely complete.

POTATO.

This cheese is made in Thuringia, in the central part of Germany. In the manufacture of potato cheese, curd is made from sour cow's milk, or in some cases from renneted milk. Sometimes sheep's or goat's milk is used. The potatoes are boiled and grated or mashed. One part of the potatoes is thoroughly mixed or kneaded with two or three parts of the curd. In the better cheese three parts of potatoes is mixed with two parts of curd. During the mixing salt is added, and sometimes caraway seed. The cheese is allowed to stand for 2 to 4 days while a fermentation takes place. After this the curd is again thoroughly kneaded and placed in forms for a day. It is then dried and is sometimes covered with beer or cream. It is finally placed in tubs and allowed to ripen for 14 days.

A variety of this cheese is made in the United States. It is probable, however, that this is not allowed to ripen for quite so long a period as the European potato cheese. In all other essentials it appears to be identically the same.

POTTED.

This cheese is very likely of domestic origin. It is usually prepared from well-ripened Cheddar cheese by grinding it very fine and mixing with butter, condiments, spirits, etc. In the past this has been put up in small porcelain jars, but at the present time a portion of it is wrapped in waxed paper and either tin or lead foil. This ordinarily goes by the name of Club cheese.

PRATTIGAU.

This is made from skimmed cow's milk and is so named from the valley of Switzerland in which it is made. Its manufacture is the same as that of Limburg. Cheeses weigh from 20 to 25 pounds.

PRESTOST.

Prestost is a product of Sweden, where it is often called Saaland Pfarr. It is a rennet cheese made from fresh cow's milk and resembles Gouda. It was known in the eighteenth century. The milk is set at 90° F. and is allowed to become very firm, when it is cut coarse with a wooden knife and poured into a sieve, which allows the whey to drain off. The curd is then put into a cloth and kneaded. Whisky is mixed with the curd, which is then packed in a basket, and after some salt is sprinkled on the surface it is put into the cellar. The cloth inclosing the cheese is changed daily for 3 days, after which the cheese is washed with whisky. A cheese is cylindrical in shape and weighs 5 to 30 pounds.

PROVIDENCE.

This cheese is aboout 8 inches in diameter and 1½ inches thick, and very closely resembles Port du Salut. It is made in the monastery of Bricquebec in the Department of Manche, France.

PROVOLE.

This is one of the most esteemed of the several kinds of hard rennet cheese made in central and southern Italy from cow's milk, including also that of buffaloes. The cheese is round or oval and weighs from 4 to 6 pounds. Smaller sizes weighing about 2 pounds are known as Provoloni. In many respects, including the cooking of the curd with hot water and the smoking of the cheese, Provole and Provoloni resemble Caciocavallo. Considerable amounts of this cheese are imported into the United States.

PULTOST.

Pultost, also called Knaost, is made usually from sour milk, but it may be made with rennet. It is a Norwegian product and is made in private dairies in the mountains of that country. The milk is placed in a kettle and if not sour enough to coagulate on warming the acidity is increased by the addition of buttermilk. When sufficient acid has developed the milk is warmed to 113° F. The curd is broken up with a scoop and stirred to keep it from matting together while it is being heated to 140°. It is then dipped and ground up fine. Buttermilk is added and the whole is thoroughly kneaded and put into troughs, where it is covered with a cloth. It is allowed to stand for three days with occasional stirring.

QUESO DE CINCHO.

This is a sour-milk cheese made in Venezuela and known also as Queso de Palma Metida. It is exported in the form of balls 8 to 16 inches in diameter and wrapped in palm leaves.

QUESO DE HOJA.

This is a Porto Rican cheese made from fresh cow's milk. The curd is cut into blocks about 6 inches square and 2 inches thick. After part of the whey is drained off, which may require several hours, the pieces of curd are immersed in water or whey having a temperature of 150° F. This gives a tough layer to the block of curd, which is then removed to a table and pressed or stretched by the use of a broad wooden spoon or paddle. Salt is sprinkled on the surface and the piece of curd is folded and wrapped in a cloth and squeezed to force out the moisture. The finished product is about 6 inches in diameter, 1 to 2 inches thick, and has slightly rounded top and bottom surfaces. When the cheese is cut it appears to be in layers like leaves upon one another, hence the name, signifying leaf cheese.

QUESO DE MANO.

This is a sour-milk cheese resembling a hand cheese, and is made in Venezuela. It is 6 to 7 inches in diameter.

QUESO DE PRENSA.

This is a Porto Rican product, and is a hard rennet cheese made from unskimmed cow's milk. The milk is allowed to stand six hours without cooling, and rennet is then added. The curd is broken by hand or with a stick, and after part of the whey is separated the curd is transferred to a table and is broken into small pieces. It is then put in wooden frames, and salt is added either as the curd goes into the frame or by sprinkling on top. Light pressure is applied, either by hand or by means of a screw. After leaving the press the cheese is placed on racks. It may be eaten fresh or allowed to stand for 2 to 3 months. The cheeses are 11 inches long, 5½ inches wide, and 3 inches thick, and weigh about 5 pounds. The name signifies pressed cheese.

QUESO DE PUNA.

This is a Porto Rican product, resembling very much the Cottage or Dutch cheese of the United States. The milk is set with rennet and the curd is thoroughly mashed or kneaded by hand, salt being added at the same time. The curd is put in a hoop 5 inches in diameter and 1½ inches deep, where it remains without pressure for 2 or 3 days, or until it will keep its form. The cheese is eaten fresh.

RABACAL.

This is a round, rather firm cheese made from the milk of sheep and goats in the vicinity of Coimbra, Portugal. A cheese is 4 to 5 inches in diameter and 1 inch thick.

RADEN.

This is a hard rennet cheese made from skim milk in Mecklenburg. The cheeses are 16 inches in diameter and 4 inches thick, and weigh 32 pounds. The process of manufacture does not differ materially from that of Emmental.

RANGIPORT.

This cheese is in every way analogous to Port du Salut. It is about 6 inches in diameter and 2½ inches thick and weighs about 2½ pounds. It is made in the Department of Seine-et-Oise, France.

RAYON.

This is a special type of Emmental cheese, made largely in the Canton of Fribourg, Switzerland, for exportation to Italy, though some is now manufactured in Italy. It is made of partly skimmed milk, and the cooking is continued to a point that insures a very dry, hard cheese, which develops no eyes. After curing it is shipped largely to Turin, where it is placed on edge on shelves in a dry, warm cave, and the fat leaks out, leaving the cheese exceedingly dry and hard, when it is used for grating. After the drying process the cheese is called Raper.

REBBIOLA.

Rebbiola, or Robiola, is a soft cheese, made principally in the Alpine districts of Italy. The process of manufacture is very simple. It is generally made from milk skimmed after 12 hours, but whole milk is sometimes used. The cheese is circular and weighs about 2 pounds. The ripening process is very rapid, requiring usually 12 to 15 days. The milk is set at a temperature of 90° F., the time allowed being usually about one-half hour. The curd is cut fine and put into molds 8 inches in diameter and 6 inches high, the bottom being perforated. Five hours later the cheeses are removed from the molds and placed on a draining board covered with straw. After 2 or 3 days they are salted and then ripened.

REBLOCHON.

This is a soft French cheese, weighing 1 to 2 pounds. It is made from fresh whole milk, which is curdled with rennet at a temperature of 80° F. or above, the time allowed being about 30 minutes. The curd is cut to the size of peas, cooked to about 95°, and after the removal of the whey is put into molds about 6 inches in diameter and 2 inches in height. A weight of about 5 pounds is placed upon each cheese, which is turned frequently and salted after about 12 hours. In a moist room having a temperature of about 60° the desired degree of ripening is secured in 4 to 5 weeks. An imitation of this cheese, made in Savoy, France, is known as Brizecon.

REINDEER MILK.

In Norway and Sweden the milk of the reindeer is sometimes used for cheesemaking. Rennet is added at 100° F., and the curd is cut and dipped into a large frame, where it is pressed lightly. The mass of curd is then cut into pieces 5 by 4 by 2½ inches, which are salted on the surface and are allowed to ripen in a dry curing room.

RIESENGEBIRGE.

This is a soft rennet cheese, made from goat's milk in the mountains on the northern border of Bohemia. The milk is set at about 90° F. The curd is broken up and the whey dipped off, after which the curd is put in forms, where it remains in a warm place for 24 hours. It is then covered with salt and after drying for 3 to 4 days is placed in the curing cellar. From each 100 pounds of milk 18 pounds of cheese is secured.

RINNEN.

This is a sour-milk cheese which was known in the eighteenth century. It is made in Pomerania from milk sufficiently acid to cause a precipitation of the curd when it is warmed to about 90° F. The cheese derives its name from the wooden trough in which it is laid to drain. The curd is broken up and heated to expel the whey. The curd is kneaded by hand and caraway seed is added. It is molded into forms and pressed. Salt is then rubbed on the outside. The cheese is dried and put in a box to ripen.

ROLL.

This is a hard rennet cheese, made in England from unskimmed cow's milk. It is cylindrical in shape, 8 inches high by 9 inches in diameter. A cheese weighs 20 pounds.

ROLLOT.

This is a soft rennet cheese, 2½ inches in diameter and 2 inches thick, made in the Departments of Somme and Oise, France.

ROMADOUR.

Romadour, Remoudou, or Romatur cheese is a southern Bavarian product similar to Limburg. It is 4½ by 2 by 2 inches in size and weighs 1 pound. It is said to be a little finer variety of cheese than Limburg and to sell for a slightly higher price.

ROQUEFORT.

This is a hard rennet cheese made from the milk of sheep. There are, however, numerous imitations or varieties closely resembling Roquefort, such as Gex and Septmoncel, made from cow's milk. One of the most striking characteristics of this cheese is the mottled or marbled appearance of the interior, due to the development of a penicillium, which is the principal ripening agent. The manufacture of Roquefort cheese has been carried on in the southeastern part of France for at least two centuries. The industry is particularly important in the Department of Aveyron, in which is situated the village of Roquefort, from which the cheese derives its name. It is also made in Corsica. Imitations of Roquefort cheese are made in various countries.

The evening's milk is heated to 140° to 150° F., cooled, and kept over night. After being skimmed it is mixed with the fresh morning's milk. The mixture is then set with rennet at a temperature of about 90°. In from 1 to 2 hours after the addition of rennet the curd is cut until the particles are about the size of walnuts. The whey which rises to the surface is dipped off and the curd is put into hoops which are about 8½ inches in diameter and 3½ inches in height. The hoops are filled usually in three layers, a layer of moldy bread crumbs being interspersed between the first and second and second and third layers. The bread used for this purpose is prepared from wheat and barley flour, with the addition of whey and a little vinegar. It is thoroughly baked and kept in a moist place for 4 to 6 weeks, during which time it becomes permeated with a growth of the mold referred to. The crust is removed and the interior is crumbled very fine and sifted. The cheese is subjected to pressure, which is gradually increased, for 10 to 12 hours. It is turned usually 1 hour after putting into hoops. At the end of about 12 hours it is wrapped in cloth and taken to the first curing room. The cloths are frequently changed during the 10 to 12 days the cheese remains in this place.

Formerly the manufacture of the cheese up to this stage was carried on by the shepherds themselves, but in recent years centralized factories have been established and much of the milk is collected and there made into cheese. The cheese is then taken to the caves. These are for the most part natural caverns which exist in large numbers in the region of Roquefort. The temperature in these caves is 40° to 45°, and the air circulates very freely through them. Recently artificial caves have been constructed and used. When the cheeses reach the caves they are salted, which serves to check the growth of the mold on the surface. One or two days later they are rubbed vigorously with cloth and are afterwards subjected to thorough scraping with knives, a process formerly done by hand but now much more satifactorily and economically by machinery. The salting, scraping, or brushing seems to check the development of mold on the surface. In order to favor the growth of mold in the interior, the cheese is pierced by machinery with 60 to 100 small steel needles, which process permits the free access of air. The cheese may be sold after 30 to 40 days or may remain in the caves as long as 5 months, depending upon the degree of ripening desired. The cheese loses during ripening by scraping and evaporation as much as 25 per cent of the original weight. The weight when ripened is about 4½ to 5 pounds.

SAANEN.

This is a type of Emmental cheese made in Switzerland from cow's milk. It is sometimes known at Hartkäse, Reibkäse, and Walliskäse. First mentioned in the sixteenth century, it is still manufactured extensively at the present time and exported to a limited extent. It sells for a higher price than the regular Emmental. The process of manufacture is identical with that of Emmental, except that it is cooked much dryer, takes much longer to cure, and keeps longer. The cheese weighs from 10 to 20 pounds. The eyes are few and small.

The ripening period is never less than 3 years and many require as long as 9 years, the average being 6 years. The cheeses are kept to great ages, it being the custom to make a cheese at the birth of a child and eat it at the burial feast or even at the burial feast of a son of the child for whom it is made. One cheese is mentioned as being 200 years old and is considered a great honor to the household. Many cheeses are kept until they are 30 years old.

SAGE.

This cheese is made by the ordinary Cheddar process, and may be of any of the various shapes and sizes in which that cheese is pressed. As seen when cut it has a green mottled appearance.

Formerly sage cheese was made by mixing green sage leaves with the curd before it was pressed. At the present time the flavor of sage is obtained by sage extract. To secure the green mottles, succulent green corn is cut fine and the juice is pressed out. A small portion of the milk is mixed with this juice and is set with rennet in a small vat while the bulk of the milk is set in the ordinary manner. After the curd is cut and is firm enough to be handled, the green curd from the small vat is mixed with the uncolored curd, and the process is continued as in the Cheddar process. This is a very popular variety of cheese with many consumers.

SAINT BENOIT.

This is a soft rennet cheese resembling Olivet, and is made in the Department of Loiret, France. Charcoal is added to the salt which is applied to the exterior of the cheese. Ripening requires from 12 to 15 days in summer and 18 to 20 days in winter. A cheese is about 6 inches in diameter.

SAINT CLAUDE.

This is a small, square, goat's-milk cheese made in the region of Saint Claude, France. The milk is curdled with rennet and the curd placed in molds for 6 to 8 hours. It is then salted and allowed to ripen, or may, however, be eaten when fresh. A cheese weighs from one-quarter to one-half pound.

SAINT MARCELLIN.

This is a goat's-milk cheese made in the Department of Isère, France. Sheep's milk or even cow's milk may be mixed with the goat's milk. A cheese is about 3 inches in diameter and three-fourths of an inch thick and weighs about one-fourth pound.

SAINT REMY.

This is a soft rennet cheese differing but little from Pont l'Évêque. It is made in the Department of Haute-Saône, France.

SALOIO.

This is a kind of hand cheese made from skimmed cow's milk on farms in the region of Lisbon, Portugal. It has the form of a short cylinder, measures 1½ to 2 inches in diameter, and weighs about 4 ounces. A similar cheese of about the same character is made in Thomar, about 50 miles north of Lisbon.

SAP SAGO.

This cheese is made from sour skimmed cow's milk, principally in Glarus, Switzerland. It is known also as Schabzieger, Glarnerkäse, Grünerkäse, and Kräuterkäse. It is claimed to have been made in the thirteenth century; the authentic history at least dates back to the fifteenth century. Sap Sago is a small, hard, green cheese flavored with the leaves of a species of clover; it is shaped like a truncated cone, 4 inches high, 3 inches in diameter at the base, and 2 inches at the top. This cheese is imported to some extent into the United States under the name of Sap Sago.

The skimmed milk from which this cheese is made is not allowed to become sour enough to coagulate on heating, as it would make too hard a curd. The milk when it has reached the right acidity is heated to the boiling temperature while being stirred. Cold buttermilk is then added, as is also some whey having a high percentage of acidity. The material coagulating on the surface is skimmed off. The milk is then stirred while sufficient acid whey is added to precipitate the casein. When too little whey is used the curd is too soft, and when too much is used it is too hard. The curd is dipped with a skimmer and spread out to cool and then put in boxes and allowed to drain and ferment. The box is kept at a temperature of about 60° F., and pressure is applied by weighting with stones. Ripening is allowed to continue for 3 to 6 weeks. If the temperature of the room is too high or there is not sufficient pressure, too rapid and strong fermentation results. This curd is used for making the finished product, but the cheese is seldom finished where the curd is made. The curd is ground in a mill, and every 100 pounds of cheese contains 5 pounds of salt and 25 pounds of dried *Melilotus cœrulea*, an aromatic clover which is grown in the Canton of Schweiz for the purpose. The ground material is worked up into a dough and is forced into molds lined with linen cloth, and the name of the manufacturer is stamped on the large end. The mold is then emptied and refilled. The cheeses are dumped promiscuously into a large cask holding about 200 pounds. A comparatively small quantity is shipped into this country. It sells at a low price and is usually grated.

SASSENAGE.

This is a hard rennet cheese, about 12 inches in diameter and 3 inches in height, made from cow's milk to which small quantities of goat's and sheep's milk are usually added. The cheese is almost identical with that of Gex and Septmoncel. It derives its name from the village of Sassenage, near Grenoble, in the Department of Isère, France. The milk used is usually a mixture of skimmed milk and whole milk. It is set with rennet, and the curd is cut and put into molds in the same manner as with the other varieties mentioned. The same is also true of the ripening process, which requires about 2 months.

SCANNO.

This is a soft rennet cheese made from the milk of sheep in the Apennine Mountains, in the Province of Abruzzo, Italy. It derives its name from the village of Scanno. The surface of the cheese is colored a deep black. The interior is bright yellow and has the consistency of butter.

SCARMORZE.

This is a small rennet cheese made in southern Italy from the milk of buffaloes.

SCHAMSER.

This cheese, which is also known as Rheinwald, is a rennet cheese made from skimmed cow's milk in the Canton Graubünden, Switzerland. The cheeses weigh from 40 to 45 pounds and are 18 inches in diameter and 5 inches high.

SCHLOSS.

Schlosskäse, or Castle cheese, is a Limburg cheese made in the northern part of Austria. It is a soft-cured rennet cheese 4 by 2 by 2 inches in size. When ready for market it is wrapped in tin foil.

SCHOTTENGSIED.

This a whey cheese made by the peasants of the Alps for home use.

SCHWARZENBERG.

This cheese is made in southern Bohemia and western Hungary. It is a rennet cheese made from partly skimmed cow's milk. One part of skimmed milk is added to two parts of fresh milk. In about 1 hour after the addition of rennet the curd is broken up and thoroughly stirred. It is then dipped into wooden forms and light pressure applied for half a day. For 4 or 5 days following the cheese is rubbed with salt and is then taken to the cellar, where it is washed daily with salt water until ripe, which requires 2 to 3 months.

SÉNECTERRE.

This is a soft rennet cheese originating at Saint Nectaire, in the Department of Puy-de-Dôme, France. It is made out of whole milk, is cylindrical in shape, and weighs about 1½ pounds.

SEPTMONCEL.

This is a hard rennet cheese made from cow's milk, to which a small proportion of goat's milk is sometimes added. It resembles the Gex and Sassenage varieties very closely, and its process of manufacture is almost identical with that of Roquefort. It is also known as Jura blue cheese. It derives its name from the village of Septmoncel, near Saint Claude, in the Department of Jura, where the cheese is for the most part made. The cheese is made almost exclusively on isolated farms rather than in coöperative dairies, and the methods employed are somewhat rudimentary.

The milk, which is usually partly skimmed, is set with rennet at a temperature of about 85° F. The curd is cut and stirred after about 1½ hours. After the curd has settled the whey is poured off. The stirring and draining are repeated several times until the curd is sufficiently firm to put into hoops. Moderate pressure is applied for a few hours. The cheese is salted at the end of 24 hours, and thereafter daily for several days. It is then transferred to the first curing room, which is kept cool and moist. After 3 to 4 weeks it has become covered with blue mold, when it is transferred to cellars or natural caves, where the ripening is completed in from 3 to 4 weeks longer.

SERRA DA ESTRELLA.

This is the most highly prized of the several kinds of cheeses made in Portugal. The name refers to the mountainous region in which the cheese is produced. It is made for the most part from the milk of sheep, but goat's milk is often added to this, or even used alone, and occasionally cow's milk is used.

The method of making this cheese is comparatively simple. The milk is warmed in a kettle with little regard to the temperature obtained, and is coagulated in most cases by means of an extract of the flowers of a kind of thistle. The time required for curdling varies from 2 to 6 hours, depending upon the amount of the extract used. The curd is broken up with a ladle or by hand, squeezed to remove most of the whey, and put into circular forms. After draining until sufficiently firm the cheeses are removed from the hoops and allowed to ripen for several weeks, during which time they are frequently washed with whey and salted on the surface. The cheeses vary much in size, the larger measuring about 10 inches in diameter and 2 inches thick, and weighing about 5 pounds. The cheese is rather soft and has a pleasant acid taste.

A similar cheese made in another part of Portugal is known as Castello Branco.

SERVIAN.

In making Servian cheese the milk is warmed in a kettle over a fire or in a tub by immersing heated stones. After the rennet is added the milk is allowed to stand 1 hour. The curd is then lifted in a cloth and the whey allowed to drain. It is then placed in a wooden vessel, salted, and covered successively with whey for about 8 days and fresh milk for about 6 days.

SILESIAN.

A cheese known locally as Schlesischer Weichquarg is made from skimmed cow's milk, the process of manufacture resembling that of hand cheese. The milk is allowed to coagulate from souring and the curd is broken up and cooked at 100° F. for a short period. The curd is then put in a cloth sack and light pressure applied for 24 hours, after which it is kneaded by hand and salt and milk or cream are added. Flavoring substances such as onions or caraway seed are also sometimes added. The cheese is eaten fresh.

Another cheese known as Schlesischer Sauermilchkäse is also made in much the same way as hand cheese. The cheeses are kept on shelves covered with straw, and are dried by the stove in winter and in a latticework house in summer. Drying is continued until the cheese becomes very hard. The cheese is ripened in a cellar, the process requiring 3 to 8 weeks, during which time it is washed every few days with warm water.

SIRAZ.

This is a Servian cheese made as a rule from whole milk. The milk is set at 104° F. and the curd is lifted from the whey with a cloth and pressed into cakes 4 to 6 inches in diameter and 1 inch thick. These cakes are placed in the sun to dry until the fat commences to run, when they are rubbed several times with salt until a good crust is formed. The cakes are then packed in a wooden vessel and allowed to ripen. The cut surface shows a smooth appearance without holes. It is between a hard and a soft cheese.

SLIPCOTE.

This cheese is made in Rutlandshire, England. It is a soft unripened rennet cheese, made from cow's milk. The curd is dipped into small forms and no pressure is applied. After the cheese is removed from the form the surface dries and cracks and is easily slipped off, hence the name. It is an old cheese, having been well known in the middle of the eighteenth century.

SPALEN.

This is a type of Emmental cheese, and is sometimes known as Stringer. Its origin is unknown. It is made largely in the Canton of Unterwalden, Switzerland, from sweet cow's milk, often partly skimmed. The name is derived from the vessel in which the cheeses are transported and in which five or six of them are packed. This is a small cheese for an Emmental type. Each cheese weighs from 35 to 40 pounds.

No thermometer is used in the manufacture, the temperature being judged by the feeling, and a very uneven product is the result. The process of making seems to vary much, the press consisting of a board with stones for weights, and the temperature of the cellar being poorly regulated.

SPITZ.

This is a small rennet cheese made from cow's milk. The cheese is cylindrical in shape, being 4 inches high and 1½ inches in diameter.

STEPPES.

This name is applied to a Russian cheese made from whole milk. The milk after the addition of coloring matter is heated to about 90° F. and treated with sufficient rennet to secure coagulation in 40 to 45 minutes. The curd is cut into large cubes, the whey removed slowly, and the curd is still further broken up until the particles are uniformly about the size of peas. The curd is then heated gradually to 100° to 104°, the mass meanwhile being gently agitated. The stirring is kept up for some time after heating ceases until the curd becomes dry, when it is placed in molds 10 by 5½ by 7 inches. After the cheeses are removed from the molds they are turned frequently and 5 hours later are salted and transferred to the curing cellar, where a temperature of about 55° is maintained. During ripening the cheeses are worked occasionally with salt water and turned frequently.

STILTON.

This is a hard rennet cheese, the best of which is made from cow's milk to which a portion of cream has been added. It was first made near the village of Stilton, Huntingdonshire, England, about the middle of the eighteenth century. It is now made principally in Leicestershire and west Rutlandshire, though its manufacture has extended to other parts of England. Its manufacture has been tried, though without success, in the United States. The cheese is about 7 inches in diameter and 9 inches high and weighs 12 to 15 pounds. It has a very characteristic wrinkled or ridged skin or rind, which is likely caused by the drying of molds and bacteria on the surface. When cut it shows blue or green portions of mold which give its characteristic piquant flavor. The price in this country is about 45 cents a pound wholesale. The cheese belongs to the same group as the Roquefort of France and the Gorgonzola of Italy.

The morning's milk is put in a tin vat and the cream from the night's milk is added, and the whole is brought to a temperature of 80° F., when the rennet is added. It is claimed by some cheese makers that the curd should be softer when broken up or cut than the curd for Cheddar cheese, while by others it is believed that it should become very firm before it is disturbed, allowing 1 to 2 hours for setting. When sufficiently firm the curd is dipped into cloths which are placed in tin strainers. After draining for 1 hour the cloths containing the curd are packed closely together in a large tub and allowed to remain for 12 hours, when they are again tightened and packed for 18 hours. The curd is ground up coarse and salt is added, 1 pound to 60 pounds of curd. The curd is then put into tin hoops 8 inches in diameter and 10 inches deep. The cheeses remain in the hoops for 6 days, when they are bandaged for 12 days, or until they become firm, and are then placed in the curing room at 65°. Ripened Stilton cheese is of late often ground up and put into jars holding 1 to 2½ pounds.

STRACCHINO.

This name is applied to several forms of Italian soft cheeses, the best known of which is Stracchino di Gorgonzola, which is described under the name of Gorgonzola. A square form 6 to 8 inches on a side and 1½ inches thick is known as Stracchino di Milano, Fresco, Quadro, or Quartirola. This cheese is prepared similarly to Gorgonzola but is allowed to ripen for only about 2 months. It is not much exported. Stracchino Crescenza is a very soft and highly colored cheese usually eaten fresh. The form is similar to that of the Quartirola. It is usually marketed in about 8 days and can not be kept long.

STYRIA.

This is a cylindrical-shaped cheese made from unskimmed cow's milk in Styria, Austria.

SWEET CURD.

This is a name applied in the United States to a hard rennet cheese made from cow's milk. The name is used to distinguish it from the ordinary Cheddar or granular process, as in making Sweet Curd cheese the milk is set sweet, and the cutting and cooking are done rapidly without regard to the development of acid. In making this cheese the curd is cooked very firm and is salted and put to press immediately. In all other respects the process is the same as for Cheddar, and the cheese when ripened resembles that cheese very closely.

SWISS.

Swiss or Schweitzer cheese belongs to the Emmental group of cheeses and is made usually from half-skimmed cow's milk. Its manufacture is very old. It is supposed to have originated in the Alps, but is now made in most of the surrounding countries. It is made mostly in the winter season, when the price of butter is high, and only for local consumption. Its manufacture differs from real Emmental in that it is made from half-skimmed milk. The morning's milk is first heated and the skimmed evening's milk is added. The curd is cut coarser and is not cooked so firm as Emmental, which gives a softer and more quickly ripened cheese.

The cheese made in the United States which goes by the name of Swiss or Domestic Swiss is in reality an imitation of the Emmental cheese, as it is made from whole milk.

TAFI.

This cheese is manufactured in the Province of Tucuman, in the Argentine Republic.

TAMIÉ.

This cheese is made by the Trappists in Savoy, France. The whole milk is heated to about 80° F. and coagulated with rennet in about 30 minutes. The curd is cut fine, cooked to about 100°, stirred, and put into molds 7 inches in diameter and 4 inches in height. The cheese is pressed for 6 to 8 hours, the cloths being changed frequently. After being salted the cheese is ripened for 5 to 6 weeks. The method of manufacture is, to a large extent, a trade secret. The Tome de Beaumont is a more or less successful imitation.

TEXEL.

This is a sheep's-milk cheese made in Holland. It was known in the seventeenth century. A cheese weighs 3 to 4 pounds and is colored green.

THENAY.

This is a soft rennet cheese resembling Camembert and Vendôme and is made in the region of Thenay in the Department of Loir-et-Cher, France. It is of comparatively recent origin, and its consumption is limited practically to the region in which it is produced.

The evening's milk without being skimmed is mixed with the fresh morning's milk. The milk is set with rennet at a temperature of about 85° F. and allowed to stand for 4 to 5 hours. The curd is then broken up and put into hoops about 5 inches in diameter and 4 inches in height. After draining for about 1 day it is turned and salted. The cheese is then kept for about 20 days in a well-ventilated room during which time it becomes covered with molds. It is then taken to the curing cellar for about 15 days.

TIGNARD.

This is a hard rennet cheese, resembling Gex and Sassenage, made from sheep's and goat's milk in the valley of the Tigne, in Savoy, France.

TILSIT.

This is a hard rennet cheese made mainly in East Prussia from unskimmed cow's milk. It is sometimes called Ragnit. The milk is set at 92° F. with sufficient rennet to coagulate in from 15 to 40 minutes. The curd is rather coarsely cut or broken and is cooked to 104° to 110°, being stirred meanwhile with a harp. The curd is cooked quite firm or until it can not be squeezed through between the fingers, which requires about 40 minutes. It is then dipped into cylindrical forms, where it remains 24 hours. The cheese is then covered thickly with salt for from 1 to 2 days, when it is put into a salt bath for 3 to 5 days and then transferred to the cellar.. Here it is rubbed and washed with salt water frequently, and allowed to ripen for 4 to 6 months. The cheese is 6 to 12 inches in diameter, 3 to 4½ inches in height, and weighs from 6 to 28 pounds. It resembles in general characteristics the Brick cheese of the United States.

TOPPEN.

This is a German sour-milk cheese made from skim milk and eaten while fresh. It is put up in small packages weighing about 1 ounce.

TRAPPIST.

This cheese originated with the Trappists in 1885 in the monastery of Mariastern, near Banjaluka, in Bosnia. The fresh milk is heated to about 85° F. and rennet is added. After 1 to 1½ hours the curd, without being cut or stirred, is put into hoops and pressed, after which it is salted and ripened. The growth of mold is entirely prevented by frequent washing, and thus the cheese ripens uniformly throughout. The ripening period of the smaller cheeses is 5 to 6 weeks in summer, but the cheese is usually shipped at the end of 4 to 5 weeks. The cheese is pale yellow in color and has a remarkably mild taste. Although this cheese is to be classed among the soft varieties, the water content is often below 45 per cent. The ripening is also more characteristic of the hard cheeses. The smallest size of the cheese made in the monastery referred to has a diameter of 6 inches, a height of 2 inches, and weighs 2 to 3 pounds. A larger size measures 9 inches in diameter, 2½ inches in height, and weighs about 10 pounds. There is also a still larger size. The cheese is exported to a large extent to Austria and Hungary, the most important centers of the trade in these regions being Gratz and Budapest. It is, however, found in all of the large cities of Austria, and the demand appears to be constantly increasing. This cheese is very probably the same as Port du Salut.

A cheese which is very likely identical with the Trappist, or Port du Salut, is made in the Trappist monastery at Oka, Canada, and goes by the name of Oka cheese.

TRAVNIK.

This is a soft rennet cheese made usually from whole sheep's milk to which a small amount of goat's milk is added. Skimmed milk, however, is sometimes used. It is also known as Arnauten and Vlasic. This cheese originated in Albania in the northwestern part of Turkey in Europe and has been made for at least a century. In the country of origin it was known at first by the name Arnautski Sir or Arnauten cheese. At the present time it is made in Bosnia and Herzegovina, but principally in the Vlasic Plain. The center of trade in this cheese is Travnik in Bosnia.

The fresh warm milk is treated with sufficient rennet to secure coagulation in one and one-fourth to two hours and is then allowed to stand for a short time until the coagulum contracts and the whey appears on the surface. The curd is then put into woolen sacks and drained for 7 to 8 hours, when it is pressed into flattened balls by hand. These are dried for a short time in the open air and then packed into wooden receptacles varying in diameter from 14 to 28 inches, having a height of about 24 inches, and holding from 50 to 130 pounds of cheese. Each layer of cheese is salted and pressed so that no air spaces are left. When the receptacle is filled the whey usually shows at the surface, any excess being removed. Moderate pressure is applied to the cover placed upon the cheese. When fresh, the cheese made from whole sheep's milk has a soft consistency, a nearly white color, and a pleasant, mild taste. The cheese, however, is usually allowed to ripen for two weeks to several months. No holes should develop in the cheese.

TROUVILLE.

This is a soft rennet cheese made in the same locality as Pont l'Évêque and is of the same nature though superior in quality. Only fresh whole milk is used. The temperature of setting with rennet is 85° to 95° F. The growth of molds during ripening is prevented by frequent washing with salt water.

TROYES.

Two kinds of cheese are referred to by this name—one a washed cheese with a yellow rind, known as Ervy, and the other a cheese very closely resembling Camembert and known as Barberey. The industry is quite restricted.

TUNA.

Tuna cheese is a Mexican product which has been of local importance from an early date. It is really a confection rather than a cheese, being made from the fruit of the *Tuna cardona*, or sometimes the *Tuna pachona*. The product is made by boiling and straining the Tuna pulp until a cheese-like consistency is reached, sometimes with the addition of nuts or flavors. It is of a chocolate color, pleasant to the taste, and wholesome. It is said to keep in good condition indefinitely.

TWOROG.

This is a sour-milk cheese made in Russia. The soured milk is kept in a warm place for 24 hours, when the whey is removed and the curd put into wooden forms and subjected to pressure. This cheese is made on a large scale by farmers and is often used in making a bread called "Notruschki."

URI.

This is a hard rennet cow's-milk cheese made in the Canton of Uri, Switzerland. It has a diameter of 8 to 12 inches and is 8 inches high. It weighs 20 to 40 pounds.

VACHERIN.

This name is applied to two quite different kinds of cheese.

The form designated Vacherin à la Main is made in Switzerland and in Savoy, France. Whole cow's milk is set with rennet at a temperature of about 85° F., and the curd is cut very fine and put into hoops 12 inches in diameter and 5 to 6 inches high. It is salted and ripened. The rind is firm and hard, but the interior is almost liquid in consistency. It is either spread on bread or eaten with a spoon. A ripened cheese weighs from 5 to 10 pounds. A cheese of this kind made in the same region is known locally as Tome de Montagne.

The form designated Vacherin Fondu is made in much the same manner as Emmental cheese. The ripened cheese is then melted and spices are added.

VENDÔME.

This is a soft rennet cheese resembling Camembert and Thenay, and is made in the region of Vendôme in the Department of Loir-et-Cher, France.

The warm morning's milk is usually mixed with that of the previous evening, which secures ordinarily a setting temperature of 75° to 85° F., which is desired. The period of setting is 4 to 5 hours in summer and 5 to 6 hours in winter. The curd is then broken up and put into hoops about 5 inches in diameter and 4 inches in height. After draining for 24 hours the cheese is turned and salted, which process is twice repeated at intervals of 12 hours. When sufficiently dried it is placed in the curing cellar, where it is often buried in ashes. This cheese is placed by some on a rank with Camembert. The principal market is Paris.

VILLIERS.

This is a soft rennet cheese made in the Department of Haute-Marne, France. It is a square cheese weighing about 1 pound.

VOID.

This is a soft rennet cheese rsembling Pont l'Évêque and Limburg. It is made in the Department of Meuse, France. The milk is set with rennet at a high temperature, the whey is removed as rapidly as possible, and the cheeses during ripening are washed frequently with salt water.

VORARLBERG SOUR MILK.

This, as the name indicates, is made from sour cow's milk. It is semicircular in shape and varies in size. It is essentially a hard cheese.

The sweet milk is put in a kettle and raised to 77° F., and sour thickened milk is added and the mixture stirred and heated to 95°, at which temperature it coagulates. While this is being stirred with a curd scoop the temperature is raised to 105°. The curd is then dipped into forms, where it is turned a few times during 24 hours. Salt is rubbed on the surface and the cheese is placed in a room having a temperature of 67°. The cheese is then placed in a cask and held for 3 days, and salt is sprinkled over the surface daily. The ripening is completed in a cellar. When ripe the cheese is greasy and has a very strong odor and flavor.

WEISSLAK.

This is a soft cured rennet cheese made from cow's milk in the Bavarian Algau, Germany. The cheese weighs about 2½ pounds, and is rectangular in shape, 4½ by 4 by 3½ inches.

WENSLEYDALE.

This cheese derives its name from the valley in Yorkshire, England, in which it is made. It is a rennet cheese made from whole cow's milk. It is cylindrical in shape and weighs from 5 to 15 pounds.

In the old method of manufacture the evening's milk is heated to 100° F., and the fresh morning's milk is added. It is set with sufficient rennet to coagulate it in 35 minutes. The breaking or cutting process requires 35 minutes, after which the curd is allowed to stand for 45 minutes at 90°. The whey is then removed, and the curd is put in vats lined with cloth and light pressure is applied for 30 minutes. The curd is broken up and allowed to drain for 1 hour. It is then milled and is pressed for 24 hours, when it is wrapped in cloth, and finally put in brine for 3 days.

In the new method of manufacture the evening's milk and morning's milk are mixed in a copper kettle, heated to 95°, and enough rennet is added to coagulate it in 45 minutes. The curd is then broken up by hand or with a breaker. The whey is removed and the curd dipped into tin hoops where it drains for 3 hours. It is then turned and drained for another 3 hours. After pressing for 24 hours the cheese is salted by immersion in brine for 3 days.

WEST FRIESIAN.

This is a rennet cheese made from skimmed cow's milk. The milk is set in a copper kettle, 1 hour being allowed for coagulation. The curd is broken up and placed in a wooden tub, where it is kneaded. The curd is allowed to stand for several hours and then salted. It is pressed for 3 hours, washed in hot water, wrapped in a fine cloth and again pressed for 12 hours. The cheese is eaten when 1 week old.

WESTPHALIA SOUR MILK.

This is a hand cheese made in Westphalia. Sour milk is stirred and heated to 100° F., and placed in a sack and the whey pressed out. The curd is then kneaded by hand and salted, butter and caraway seed or pepper being added. It is then molded by hand, dried for a few hours, and ripened in a cellar.

WHITE.

Fromage Blanc, or White cheese, is a skim-milk cheese made in France during the summer months. The milk is set with rennet at about 75° F. The curd is usually molded into cylindrical forms. The cheese is consumed while fresh and may or may not be salted.

WITHANIA.

This is so called because made with rennet manufactured from withania berries. Cheese made with the rennet of these berries is said to have an agreeable flavor if ripened to the right degree, but it develops an acrid flavor with age. The texture is not so good as with animal rennet. This form of rennet is recommended for use in India, where the religion and prejudice of the people make the use of animal rennet impractical.

ZIEGEL.

This is a cheese made in Austria either from whole cow's milk or from whole milk to which 15 per cent of cream has been added. The cheese measures 3 by 2 by 2½ inches, and weighs about one-half pound.

In making the whole-milk cheese the milk is warmed to 95° F. and sufficient rennet is added to coagulate it in 30 minutes. The curd is broken up with a harp and cut loose from the bottom of the vessel, after which it is allowed to remain undisturbed for 30 minutes. At the end of this time the curd, which is again matted together, is cut into pieces and stirred gently for a considerable time, after which it is allowed to stand again for 15 minutes. The collected whey is then dipped off and the curd is dipped into forms which are 24 inches long, 5 inches high, and hold the curd of 7½ to 8 gallons of milk. Before the form is filled a cheese cloth is placed in it which helps in turning the curd. The curd remains in the form 24 hours to drain and is then cut into measured sizes and placed in another form, where it is allowed to remain for 8 days, the curd being turned and the board on which the form rests being changed daily. Salt is then sprinkled on the cheese and for 1 month it is washed in salt water and rubbed with the hands every day. It is ready for market in 8 weeks from the time of making.

ZIGER.

This is a cheese made from the whey obtained in the manufacture of other cheese. It consists principally of albumin, but where no effort is made to separate the fat from the whey the product may contain a relatively high proportion of fat. It is a cheap food product made in all the countries of central Europe. Among the many names applied to it are Albumin cheese, Recuit, Ricotta, Broccio, Brocotte, Sérac, and Ceracee.

In the manufacture of this product an effort is sometimes made to remove the fat remaining in the whey, but in most cases the fat is allowed to remain. Where it is desired to skim the whey a small portion of very sour whey, previously prepared, is added to the sweet whey and the whole is heated to 160° to 175° F. for a few minutes, when the fat collects on the surface and can be skimmed off. Following this a greater portion of sour whey is added and the whey is then heated nearly to the boiling point, when the albumin is precipitated in a flocculent condition and rises to the surface of the whey. When the whey is not in normal condition the albumin may be precipitated in a powdery mass. This is often prevented by adding 3 to 5 per cent of buttermilk to the whey before the last heating. The casein of the buttermilk is precipitated, the albumin being carried with it. It is considered that this addition of casein injures the product. The albumin when skimmed from the whey is salted and packed in a vessel and may be covered with whey.

A so-called formed Ziger cheese is made by molding the half-dried albumin into squares which may be still further dried. Some of these have local names, such as the Hudelziger made in the Canton of Glarus, Switzerland.

In Vorarlberg the albumin is skimmed from the whey, allowed to cool, placed in cheese cloth, and subjected to increasing pressure in an Emmental cheese press. After 24 hours the cheese is put into a salt bath to which sweet cider and vinegar are sometimes added.

A mixture of Ziger and cream prepared in the Savoy is known as Gruau de Montagne. An albumin cheese made from the whey of goat's-milk cheese in the Canton of Graubünden, Switzerland, is known as Mascarponi.

ANALYSES OF CHEESE.

Variety.	Authority.[a]	Number of analyses.	Water.	Fat.	Proteids, amids, etc.	Milk sugar, lactic acid, etc.	Total ash.	Salt in ash.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Alemtejo	Hoffman	1	30.22	38.25	20.87	3.06	7.60	2.90
	Pereira	4 Average	41.11	27.49	21.45	4.66	6.07	2.05
		Maximum	48.39	31.59	24.33	5.24	6.40	3.20
		Minimum	32.97	25.27	17.77	3.82	5.87	1.18
Backstein	Fleischmann	2	73.12	2.76	19.84	2.17	2.11	....
			61.04	6.80	23.85	3.48	4.83	....
	Lindt	2	45.24	28.16	23.14	....	3.46	....
			35.80	37.40	24.44	....	2.36	....
Battelmatt	Eugling	7 Average	47.71	24.08	22.99	2.35	2.87	....
		Maximum	50.53	29.42	24.48	3.35	3.14	....
		Minimum	44.24	20.52	21.22	2.25	2.71	....
Bellelay	Benecke	1	39.62	30.10	25.70	....	4.72	3.35
	Lindt	1	37.59	30.05	28.88	....	3.48	....
Bondon	Chattaway	1	39.50	24.40	9.40	....	.70	....
	Lindet	1	54.30	23.00	16.10	....	5.00	4.30
Brick	Weems	1	38.69	28.86	23.80	....	4.20	....
Brie	Balland	2	48.80	22.45	19.94	4.85	3.96	....
			43.90	28.93	19.04	6.63	1.50	....
	Blyth	1	51.90	24.80	18.10	....	5.00	....
	Duclaux	5 Average	50.04	27.50	18.34	....	4.12	3.22
		Maximum	53.84	29.50	19.94	....	4.37	3.70
		Minimum	46.06	24.60	17.16	....	3.57	2.67
	von Klenze	1	55.69	21.42	17.29	....	5.60	....
	Lindet	1	53.50	22.50	18.00	....	4.00	3.20
	Payen	2	53.99	24.83	14.94	....	5.63	....
			45.25	25.73	18.48	4.93	5.61	....
Brie—American	Arnold	1	41.50	36.15	17.63	....	4.70	....
	Johnson	1	60.20	20.96	15.94	1.37	1.53	.40
Brinsen	Maior	2	49.20	22.30	23.10	1.00	4.40	....
			37.70	32.60	25.20	2.70	5.80	....
	Melikoff	3	43.10	27.70	19.90	1.20	7.30	....
			49.70	27.00	14.30	1.80	6.80	....
			52.20	26.20	14.40	1.30	6.00	....
Burgundy	Balland	1	29.50	38.55	28.84	1.65	1.46	....
Caciocavallo	Sartori	2	19.76	36.71	37.83	....	5.60	3.26
			22.09	35.90	36.06	....	5.80	3.16
	Spica	9 Average	23.68	25.49	29.25	....	7.63	3.39
		Maximum	33.24	30.09	35.09	....	10.50	6.23
		Minimum	15.34	19.00	22.16	....	5.79	2.10
Caerphilly	Chattaway	1	24.80	30.40	37.20	....	3.40	....
Cambridge	Chattaway	1	32.10	47.10	24.60	....	4.40	....
Camembert	Arnold	1	50.41	20.55	25.49	....	3.52	....
	Balland	1	49.00	21.65	18.72	5.95	4.68	....
	Chattaway	2	47.90	21.90	21.80	....	4.70	....
			43.40	22.60	24.40	....	3.80	....
	Duclaux	1	45.24	30.31	19.75	....	4.70	3.69
	Krüger	1	59.42	17.24	17.13	4.70	1.56	....
	Lindet	1	53.80	22.00	17.10	....	4.40	3.20
	Macoir	1	49.87	25.54	18.76	....	5.83	4.01
	Muter	1	48.78	21.35	21.07	....	3.46	....
	Payen	1	51.94	21.05	18.90	4.40	4.71	....
	Rollet	1	52.98	23.71	19.12	....	4.19	3.21
	Stutzer	1	50.90	27.30	18.66	....	3.14	2.21
Cantal	Balland	3	28.50	34.10	28.38	4.46	4.56	....
			35.10	28.30	24.98	7.22	4.40	....
			39.00	26.90	24.22	5.93	3.95	....
	Duclaux	4 Average	43.48	25.70	22.55	6.47	....	2.05
		Maximum	44.80	31.10	24.10	7.50	....	3 10
		Minimum	40.70	22.50	21.50	4.30	....	.80
	Lindet	1	40.90	29.30	20.50	....	4.80	2.60
	Patrick (2)	1	39.92	28.14	28.84	....	4.50	....

[a] See Sources of analytical data for details.

Analyses of cheese—Continued.

Variety.	Authority.	Number of analyses.	Water.	Fat.	Proteids, amids, etc.	Milk sugar, lactic acid, etc.	Total ash.	Salt in ash.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Cheddar—American	Caldwell	8 Average	34.04	35.56	26.87	....	3.40	....
		Maximum	38.50	41.03	28.15	....	4.05	....
		Minimum	28.11	31.19	25.57	....	2.71	....
	Clark	79 Average	24.93	32.62	38.01	....	4.42	....
		Maximum	40.04	52.63	55.27	....	8.86	....
		Minimum	3.55	23.20	27.67	....	2.41	....
		89 Average	31.97	27.72	34.62	....	3.54	....
		Maximum	38.16	36.94	41.47	....	4.22	....
		Minimum	26.64	19.58	28.73	....	2.59	....
		13 Average	41.15	15.39	40.10	....	3.33	....
	Cooke	3	35.38	32.50	23.91	....	3.73	....
			37.56	27.70	25.58	....	3.96	....
			34.62	37.52	20.19	....	3.71	....
	Drew	201 Average	31.05	35.54	33.41	....	....	....
	Goessmann	6 Average	40.32	26.05	29.89	....	3.74	....
		Maximum	45.41	37.32	34.94	....	5.14	....
		Minimum	35.83	15.77	22.13	....	2.35	....
	Patrick (1)	15[a] Average	33.09	38.78	21.93	1.99	4.09	....
		Maximum	38.36	49.56	31.76	2.34	4.73	....
		Minimum	26.48	24.77	15.38	1.65	2.43	....
	Snyder	5 Average	32.71	35.25	26.81	....	....	....
	Van Slyke	50[b] Average	37.14	34.65	23.64	....	[c]4.57	....
		156[d] Average	36.84	33.83	23.72	....	[c]5.61	....
		Maximum	43.89	36.79	26.11	....	7.02	....
		Minimum	32.69	30.00	20.80	....	3,12	....
		9[e] Average	36.06	34.43	24.45	.61	3.61	....
		Maximum	41.15	45.36	28.72	.76	5.29	....
		Minimum	32.23	23.27	18.45	.51	1.81	....
		6[f] Average	34.01	36.81	25.69	....	[c]3.50	....
		Maximum	38.10	44.33	30.09	....	4.59	....
		Minimum	29.85	27.22	21.53	....	2.72	....
	Voelcker	4 Average	32.39	31.44	26.57	5.02	4.57	1.49
	Wallace	15[g] Average	36.42	36.95	21.15	1.36	3.81	....
		Maximum	41.65	46.80	32.09	2.68	4.61	....
		Minimum	30.25	21.77	14.11	.41	2.55	....
	Wilson	3	30.53	41.58	23.38	2.45	2.06	....
			31.70	36.18	27.19	1.95	2.98	....
			43.82	5.98	45.04	3.12	2.06	....
Cheddar—Canadian	Chattaway	1	33.30	30.60	27.60	....	3.60	....
	Clark	11 Average	34.07	22.54	40.02	....	3.45	....
		Maximum	36.58	25.67	43.52	....	3.93	....
		Minimum	32.28	20.13	33.82	....	3.14	....
	Shuttelworth	5[g] Average	34.60	35.51	23.18	....	[c]6.70	....
		6 Average[h]	32.53	36.06	23.94	....	[c]7.48	....
		135 Average[g]	36.54	33.81	23.96	....	[c]5.69	....
		135 Average[i]	33.51	32.97	24.94	....	[c]8.58	....
Cheddar—English	Blyth	2 Average	28.10	22.50	45.60	....	4.10	....
	Chattaway	4 Average	35.00	29.02	27.72	....	3.12	....
		Maximum	37.70	30.50	29.00	....	4.30	....
		Minimum	33.00	25.60	26.70	....	3.90	....
	Griffiths	1	36.34	34.36	22.98	2.10	4.22	....
	Hassall	1	30.10	36.54	30.15	....	3.21	....
	Jones	1	36.04	30.40	28.98	....	4.58	....
	Lloyd	31 Average	35.52	30.33	30.04	....	4.05	....
		Maximum	37.73	34.65	35.10	....	4.60	....
		Minimum	32.85	24.00	22.77	....	3.40	....
	Voelcker	13 Average	35.16	30.45	27.80	3.16	3.42	.70
		Maximum	39.43	41.58	32.37	6.80	4.31	1.55
		Minimum	30.32	23.21	23.28	.22	2.06	.09
	Von Klenze	1	35.22	27.91	33.47	....	3.40	....
Cheddar—Queensland	Brünnich	2	31.62	35.17	24.59	....	4.09	1.44
			27.67	37.35	26.24	....	4.04	....

[a] The 15 analyses are each the average of 5 monthly analyses. The green cheese was analyzed by Wallace.

[b] Green cheese made at New York State Agricultural Experiment Station, 1892.

[c] Sugar, ash, etc.

[d] Green cheese made at numerous factories in New York, 1892 and 1893.

[e] Age of cheese, seven weeks.

[f] Age of cheese, five months.

[g] Green cheese

[h] Age of cheese, 1 month.

[i] Cured cheese.

Analyses of cheese—Continued.

Variety.	Authority.	Number of analyses.	Water.	Fat.	Proteids, amids, etc.	Milk sugar, lactic acid, etc.	Total ash.	Salt in ash.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Cheshire	Arnold	1	24.69	37.08	33.36	......	4.85	......
	Balland	1	22.60	39.50	27.16	6.80	3.94	......
	Blades	6 Average	44.59	21.55	29.25	......	4.61	......
		Maximum	52.60	30.67	32.95	......	5.00	......
		Minimum	36.10	9.85	24.44	......	3.90	......
	Chattaway	2	37.80	31.30	25.70	......	4.20	......
			31.60	35.30	26.50	......	4.40	......
	Griffiths	1	27.55	36.00	31.00	2.21	3.24	......
	Lindet	1	31.10	32.30	30.90	......	3.70	1.30
	Payen	2	30.39	25.48	34.75	......	4.78	......
			35.92	26.34	25.99	7.59	4.16	......
	Voelcker	2	36.96	29.34	24.08	5.17	4.45	1.91
			32.59	32.51	26.06	4.53	4.31	1.59
Cotherstone	Griffiths	1	38.20	30.25	23.82	3.81	3.92	......
	Voelcker	2	38.28	30.89	23.93	3.70	8.20	.79
			38.23	29.12	24.38	2.76	5.51	2.55
Coulommiers	Balland	1	50.40	20.45	17.41	4.80	6.94	......
	Lindet	2	53.00	21.50	16.90	......	5.70	4.80
			57.80	25.00	13.00	......	4.10	3.60
Cream—English	Chattaway	2	57.60	39.30	19.00	......	3.40	......
			14.00	68.10	20.10	......	1.20	......
	Hassall	1	30.34	67.32	2.02	......	.32	......
	Payen	1	9.48	59.88	18.40	5.77	6.47	......
	Vieth	8 Average	36.49	56.08	5.28	1.27	.82	......
		Maximum	47.94	66.80	8.77	2.50	1.48	......
		Minimum	27.69	43.76	2.00	.22	.44	......
Cream—French Demi-Sel	Balland	1	52.10	25.20	13.49	8.28	.93	......
	Lindet	1	49.60	34.00	11.80	......	3.00	2.40
Crescenza	Duclaux	1	56.75	21.34	18.91	......	2.90	1.34
Danish Export	Storch	9 Average	45.99	13.41	30.01	5.10	3.63	1.86
		Maximum	49.88	23.70	34.00	5.90	4.17	2.55
		Minimum	38.78	9.34	27.69	2.65	3.33	1.11
Derbyshire	Sheldon	1	31.60	35.20	24.50	4.38	4.24	......
Dorset	Griffiths	1	41.44	27.56	22.25	4.24	4.51	......
	Vieth	1	41.55	8.76	44.09	......	5.60	2.93
Dunlop	Jones	1	38.46	31.86	25.87	......	3.81	......
Edam	Arnold	2	29.23	28.71	33.89	......	8.14	......
			29.56	27.43	32.31	......	8.49	......
	Balland	2	37.90	25.90	27.32	4.08	4.80	......
			38.50	24.29	25.34	9.07	2.80	......
	Cribb	4 Average	51.66	11.85	26.82	......	6.04	......
		Maximum	60.38	24.40	31.92	......	7.33	......
		Minimum	41.70	3.83	24.00	......	5.54	......
	Dahl	3	32.57	32.19	23.98	6.35	4.67	......
			33.62	33.99	23.48	6.34	2.42	......
			42.85	26.73	19.39	5.15	5.62	......
	Hassall	1	30.10	27.57	32.81	......	6.84	......
	von Klenze	1	41.88	24.05	29.47	......	4.60	......
	Lindet	1	42.60	20.00	23.90	......	5.50	3.20
	Mayer	1	33.20	28.00	29.60	2.60	6.60	3.30
	Patrick (2)	1	32.80	29.58	28.41	......	5.55	......
	Payen	2	36.10	27.54	29.43	......	6.93	......
			41.41	25.06	25.63	......	6.21	......
Edam—American	Haecker	3 [a]	48.69	23.21	21.49	3.83	3.02	......
			44.44	25.37	22.69	3.79	2.59	......
			46.80	23.30	24.24	2.92	3.68	......
	Van Slyke	18 [a] Average	47.55	24.42	22.18	......	[b] 5.80	......
		Maximum	55.34	31.75	24.70	......	9.46	......
		Minimum	41.25	19.73	18.95	......	2.51	......
Emmental	Benecke	7 Average	37.77	23.92	30.97	......	6.85	3.80
		Maximum	47.54	34.70	37.65	......	11.09	7.59
		Minimum	30.49	5.75	25.51	......	4.60	1.19
	Hornig	1	33.53	30.29	29.99	.31	5.88	......
	von Klenze	1	35.18	27.99	32.23	......	4.60	......
	Lindt	5 Average	33.00	30.50	30.34	......	4.17	......
		Maximum	37.44	33.37	37.51	......	4.95	......
		Minimum	24.17	28.54	30.44	......	3.38	......
Engandine	do	1	47.30	11.40	36.34	......	4.96	......
Formaggini di Lecco	Cornalba	2	61.00	19.20	16.37	......	3.43	1.90
			16.66	41.50	35.80	......	6.10	3.00
Gammelost	Voelcker	1	42.44	3.36	42.12	9.85	2.22	......
Gervais	Balland	4 Average	51.58	31.98	11.30	4.29	.60	......
		Maximum	58.00	40.47	19.94	7.09	1.42	......
		Minimum	44.70	26.85	7.20	2.13	.25	......
	König	1	52.94	29.75	11.80	2.58	2.93	......
	Richmond	1	33.80	57.79	7.90	......	.50	......
	Stutzer	1	44.84	36.73	15.48	......	2.95	.76

[a] Green cheese.

[b] Sugar, ash, etc.

Analyses of cheese—Continued.

Variety.	Authority.	Number of analyses.	Water.	Fat.	Proteids, amids, etc.	Milk sugar, lactic acid, etc.	Total ash.	Salt in ash.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Gex	Balland	2	31.50	28.85	29.96	5.51	4.18	......
			32.10	32.20	29.86	.34	5.50	......
Gislev	Böggild	1	49.22	2.96	41.53	......	......	......
Gloucester	Bell	1	35.75	28.35	31.10	.31	4.49	......
	Blyth	1	21.40	25.40	48.10	......	4.10	......
	Chattaway	2	33.10	23.50	31.80	......	5.00	......
			37.40	28.10	28.30	......	4.60	......
	Griffiths	1	34.10	37.92	21.68	1.98	4.32	......
	Hassall	1	32.52	29.94	31.70	......	5.84	......
	Jones	1	35.81	21.97	37.96	......	4.25	......
	Voelcker	13 Average	34.80	28.02	27.96	4.37	4.53	1.34
		Maximum	40.88	33.68	31.75	7.44	5.70	2.04
		Minimum	28.10	22.70	24.50	1.22	3.56	.85
Goat-milk—French	Balland	1	20.80	25.90	33.60	15.30	4.40	......
	Lindet	1	64.80	9.20	17.10	......	5.80	4.90
	Patrick (2)	1	17.73	46.64	27.90	......	4.74	......
Goat-milk—Norwegian	Werenskiold	8 Average	20.90	19.86	7.62	46.81	6.06	......
		Maximum	26.53	32.68	10.63	58.07	6.57	......
		Minimum	15.53	10.98	4.43	39.04	5.14	......
Gorgonzola	Bell	1	31.85	27.88	34.34	1.35	4.58	2.11
	Chattaway	2	40.30	26.10	27.70	......	5.30	......
			33.90	26.70	25.80	......	4.60	......
	Duclaux	2	42.80	29.70	23.14	......	4.36	2.21
			38.69	34.07	22.78	......	4.46	2.64
	Hornig	1	36.72	33.69	25.67	.21	3.71	......
	von Klenze	1	26.81	35.29	33.80	......	4.10	......
	Lindet	1	41.50	29.00	19.70	......	4.80	2.60
	Maggiora	3	34.41	37.52	26.75	......	4.08	1.33
			32.43	34.08	25.94	......	[a]6.77	.99
			37.63	36.19	26.94	......	[a]10.46	.92
	Musso	7 Average	37.30	34.67	25.16	1.62	3.82	......
		Maximum	47.10	39.32	28.51	2.00	4.63	......
		Minimum	29.82	29.00	20.33	.91	3.13	......
	Soxhlet	1	43.56	27.95	24.17	......	4.32	......
Gouda	Arnold	1	21.90	24.81	46.95	......	6.32	......
	Cribb	11 Average	54.79	9.02	25.94	......	5.52	......
		Maximum	60.17	18.37	34.22	......	7.30	......
		Minimum	50.46	1.64	22.05	......	4.26	......
	Mayer	1	38.80	31.20	24.40	......	5.60	2.80
	Patrick (2)	1	35.23	29.40	27.01	......	5.41	......
	Vieth	1	42.58	16.18	37.43	......	3.81	3.68
Gouda—American	Haecker	3 [b]	46.03	31.13	18.01	3.04	2.55	......
			46.52	29.04	19.25	3.18	2.88	......
			46.59	28.29	19.64	3.40	3.12	......
Gruyère	Balland	9 Average	29.99	28.19	33.03	4.82	3.96	......
		Maximum	33.10	33.40	37.80	7.40	4.70	......
		Minimum	27.50	23.10	29.54	1.50	3.50	......
	Benecke	1	40.61	26.59	26.18	1.94	4.68	2.10
	Chattaway	2	28.20	28.60	31.30	......	4.70	......
			35.70	31.80	28.70	......	3.70	......
	Duclaux	1	36.00	29.29	30.84	......	3.87	.57
	Lindet	1	35.70	28.00	28.90	......	3.50	.40
	Lindt	2	34.57	29.12	32.51	......	3.80	......
			35.74	30.64	29.95	......	3.67	......
	Payen	2	40.00	24.00	31.50	1.50	3.00	......
			32.05	28.40	33.75	......	4.79	......
Harz Hand	Vieth	1	55.79	1.34	37.01	......	5.86	4.16
	Vieth	3	50.19	1.64	27.72	[c]14.80	5.65	......
			52.49	1.83	22.43	[c]18.00	5.25	4.12
			52.75	1.11	19.38	[c]21.40	5.36	4.08
Hervé	Balland	1	37.50	23.93	20.86	7.71	10.00	......
Ilha	Hoffmann	1	28.39	32.00	30.62	2.85	6.14	1.66
	Pereira	1	36.89	27.15	24.30	7.71	3.95	1.50
Incanestrato	Spica	14 Average	29.07	24.74	30.09	......	9.46	5.04
		Maximum	32.48	37.48	38.66	......	12.70	8.12
		Minimum	26.02	15.88	25.16	......	4.58	.78
Kajmak	Zega	10 Average	31.55	55.79	6.25	2.01	4.50	3.07
		Maximum	36.03	63.82	8.73	3.20	8.38	7.36
		Minimum	23.97	50.16	4.94	.42	2.61	1.10
Kascaval	Maior	2	50.50	14.10	28.10	2.50	4.80	......
			39.10	25.50	28.00	1.40	6.00	......
Katschkawalj	Zega	16 Average	35.25	31.24	24.25	2.84	6.42	3.95
Krutt	Leutner	2	8.59	1.31	78.68	1.93	9.46	8.01
			10.14	1.45	69.74	.81	17.84	13.34

[a] Abnormally high ash content was due to a gypsum preparation with which the cheese was coated.

[b] Green cheese.

[c] Caraway seed.

Analyses of cheese—Continued.

Variety.	Authority.	Number of analyses.	Water.	Fat.	Proteids, amids, etc.	Milk sugar, lactic acid, etc.	Total ash.	Salt in ash.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Laguiole	Balland	1	34.50	25.20	28.70	6.15	5.45	......
Leicestershire	Griffiths	1	34.77	28.00	27.86	5.21	4.16	......
	Voelcker	2	35.21	27.28	27.93	5.54	4.04	1.03
			32.89	29.28	29.06	4.42	4.35	1.21
Leyden	Mayer	1	46.90	11.00	35.90	1.00	5.20	1.40
Limburg—American	Arnold	4 Average	35.64	29.82	28.53	......	5.98	......
		Maximum	48.60	34.98	35.05	......	6.69	......
		Minimum	23.26	21.29	23.58	......	4.82	......
	Johnson	1	42.12	29.40	23.00	.38	5.10	3.51
Livarot	Balland	1	33.80	21.95	31.76	8.05	4.44	......
	Lindet	1	52.20	15.00	25.90	......	4.40	2.90
Mainz Hand	von Klenze	1	53.74	5.55	37.33	......	3.38	......
Maroilles	Lindet	1	40.30	33.50	20.20	......	4.50	3.30
	Payen	1	40.07	28.73	23.31	......	5.93	......
Mascarpone	Fascetti	2	45.88	45.30	8.14	......	.68	......
			43.38	49.50	7.62	......	.50	......
Mont-d'Or	Balland	1	43.20	23.97	20.10	8.84	3.89	......
	Lindet	1	58.70	9.70	25.30	......	4.30	1.90
Münster	Balland	2	45.40	25.90	16.86	6.88	4.96	......
			37.50	29.83	18.17	9.75	4.75	......
	Lindet	1	52.40	24.40	15.50	......	5.00	3.70
Mysost	Dahl	6 Average	23.57	16.26	8.88	44.84	4.76	......
		Maximum	26.49	20.98	10.78	53.03	6.09	......
		Minimum	18.58	9.63	6.79	30.75	3.28	......
	Voelcker	1	24.21	20.80	9.06	41.01	4.92	......
	Werenskiold	22 Average	29.43	4.08	7.66	53.24	5.75	......
		Maximum	38.01	10.54	9.19	61.38	6.38	......
		Minimum	24.37	.07	6.34	46.00	5.06	......
Neufchâtel	Balland	2	50.80	25.15	17.60	5.12	1.33	......
			54.80	20.59	14.43	5.98	4.20	......
	Blyth	1	37.90	41.30	23.10	......	3.40	......
	von Klenze	1	51.72	23.99	20.73	......	3.56	......
	Martin	2	56.08	23.34	16.67	1.42	2.49	1.44
			57.83	21.00	17.00	1.32	2.85	1.90
	Payen	2	34.47	41.91	13.03	6.96	3.63	......
			36.58	40.71	14.18	9.02	.51	......
Neufchâtel—American	Arnold	1	37.45	34.60	24.04	......	3.90	......
	Johnson	1	57.25	22.30	15.03	2.94	2.48	1.42
Nögelost	Dahl	3	48.51	6.13	32.72	8.59	3.79	......
			47.12	7.36	31.63	10.36	3.41	......
			40.54	16.87	31.29	7.90	3.17	......
	Voelcker	3	43.87	15.89	29.93	6.47	4.84	......
			45.39	9.97	33.12	6.39	5.13	......
			42.44	3.36	42.12	9.85	2.22	......
Olivet	Balland	1	28.40	48.16	13.98	5.16	4.30	......
Olmütz	Hornig	1	44.54	3.37	41.04	.16	10.89	......
	Soxhlet	1	52.49	7.70	38.02	......	1.79	......
Parmesan	Arnold	1	23.01	12.49	55.85	......	8.14	......
	Chattaway	1	32.50	17.10	43.60	......	6.20	......
	Duclaux	2	30.09	26.04	38.42	......	5.45	1.76
			32.56	21.75	42.27	......	5.07	1.65
	Lindet	1	34.00	23.00	35.00	......	5.20	1.70
	Manetti	8 Average	32.16	19.13	43.54	......	6.29	......
		Maximum	36.11	23.42	48.93	......	7.18	......
		Minimum	30.20	12.58	38.33	......	5.20	......
	Patrick (2)	1	35.39	19.72	35.55	......	4.82	......
	Payen	2	27.56	15.95	44.08	6.60	5.72	......
			30.31	21.68	34.25	......	7.09	......
	Soxhlet	1	34.57	24.05	35.15	......	6.23	......
Pecorino	Sartori	4 Average	29.80	30.51	33.51	......	6.24	4.95
		Maximum	32.90	31.30	35.59	......	6.84	5.51
		Minimum	27.47	29.96	30.74	......	5.31	4.34
Petit Suisse	Lindet	1	54.60	35.00	7.30	......	.60	.10
Pineapple	Clark	2	3.59	54.56	36.60	......	5.25	......
			5.20	46.46	43.28	......	5.06	......
	Johnson	4 Average	24.07	38.12	29.35	2.49	5.69	2.24
		Maximum	30.95	45.20	34.45	2.75	6.18	2.61
		Minimum	11.62	33.26	27.00	2.16	5.10	1.86
Pont-l'Évêque	Arnold	1	44.57	21.80	30.36	......	3.97	......
	Balland	1	46.40	25.00	20.32	6.68	1.60	......
	Lindet	1	51.00	23.10	17.80	......	4.00	1.90
Pont-l'Évêque—American	Arnold	1	26.02	50.80	20.64	......	2.54	......
Port du Salut	Balland	1	27.70	35.10	31.16	2.04	4.00	......
	Duclaux	2	47.51	25.93	22.56	......	4.00	1.90
			48.02	24.00	24.29	......	3.69	1.58
	Lindet	1	38.10	24.50	24.80	......	5.30	2.20
	Rollet	1	46.46	26.31	23.66	......	3.67	1.31

Analyses of cheese—Continued.

Variety.	Authority.	Number of analyses.	Water.	Fat.	Proteids, amids, etc.	Milk sugar, lactic acid, etc.	Total ash.	Salt in ash.
Potted—								
American Club House	Weems	1	*Per ct.* 38.98	*Per ct.* 34.01	*Per ct.* 21.13	*Per ct.*	*Per ct.* 1.49	*Per ct.* ......
Imperial	Weems	1	30.63	33.10	26.88	......	4.22	......
Royal Paragon	Weems	1	32.85	31.52	27.74	......	4.13	......
Rabacal	Hoffmann	1	16.45	37.36	35.00	2.93	8.26	2.42
Rebbiola	Cornalba	2	46.56	25.55	19.99	......	7.90	5.80
			45.36	30.56	20.21	......	3.73	1.22
Reblochon	Lindet		53.20	20.50	19.30	......	3.70	1.80
Reindeer milk	Werenskiold	1	27.70	43.11	23.79	2.97	2.43	......
Romadour	Hornig	2	56.60	17.05	18.76	.81	6.78	......
			51.21	9.16	33.60	.02	6.01	......
	von Klenze	1	43.21	10.56	30.18	......	6.10	......
	Lindet	1	60.40	11.90	19.00	......	5.00	3.90
	Patrick (2)	1	55.16	14.76	26.05	......	5.47	......
	Vieth	1	44.55	16.16	32.72	......	6.57	5.80
Roquefort	Arnold	3	28.35	29.98	32.84	......	8.82	......
			28.87	33.70	28.82	......	8.66	......
			22.47	34.02	34.99	......	8.24	......
	Balland	1	28.90	38.30	25.16	3.00	4.04	......
	Bell	1	32.26	34.38	27.16	1.32	4.88	......
	Chattaway	1	29.60	30.30	28.30	......	6.70	......
	Hornig	1	36.93	31.23	25.79	......	4.78	......
	Johnson	1	39.28	29.53	22.62	1.77	6.80	5.27
	von Klenze	1	38.94	34.14	21.92	......	5.00	......
	Lindet	1	36.90	29.50	20.50	......	7.00	5.10
	Muter	1	21.56	35.96	32.24	......	10.24	......
	Patrick (2)	1	34.37	34.54	24.40	......	6.16	......
	Payen	2	26.53	32.31	31.69	......	4.45	......
			34.55	30.14	26.52	3.72	5.07	......
	Sieber	2	23.54	40.13	27.00	......	6.27	......
			36.93	31.23	25.79	......	4.78	......
Ricotta	Sartori	1 [a]	68.47	5.22	18.72	3.97	3.62	......
	Sartori	3 [b]	43.80	36.46	8.66	10.36	.72	......
			42.48	31.64	13.61	11.49	.78	......
			43.29	31.90	12.94	10.75	1.02	......
Saloio	Hoffmann	1	76.25	1.78	11.37	5.28	5.32	2.49
	Pereira	2	54.37	25.84	13.63	2.96	3.20	2.04
			45.81	27.80	15.16	5.97	5.26	3.17
Sap Sago	Arnold	1	13.30	15.52	57.59	......	13.57	......
	Benecke	1	47.02	6.60	37.06	......	10.10	7.53
	von Klenze	1	38.17	12.27	45.73	......	3.83	......
Savoy	Balland	2	52.40	5.90	28.84	9.38	3.48	......
			49.70	6.45	27.32	12.53	4.00	......
Septmoncel	Balland	1	28.20	31.25	32.06	3.99	4.50	......
Serra da Estrella	Büttner	5 Average	43.58	27.69	22.02	2.69	4.00	......
		Maximum	47.98	34.56	24.03	6.13	4.35	......
		Minimum	35.22	19.70	20.40	1.55	3.51	......
	Hoffmann	1	31.87	40.05	22.18	2.24	3.66	.89
	Pereira	12 Average	39.34	27.93	23.48	3.93	5.79	2.57
		Maximum	50.07	37.93	32.10	6.78	8.96	5.26
		Minimum	24.38	19.30	17.83	.78	3.23	.94
Servian	Zega	14 Average	53.99	19.30	21.32	2.63	3.30	1.86
		Maximum	68.84	32.20	32.37	5.12	4.81	3.13
		Minimum	42.10	7.77	14.66	85	2.40	.93
Spalen	Benecke	1	28.14	33.69	30.78	2.55	7.38	4.46
Stilton	Chattaway	3	19.40	42.20	21.10	......	2.60	......
			21.20	45.80	26.30	......	2.90	......
			25.00	34.60	28.40	......	4.10	......
	Griffiths	1	31.22	37.24	24.28	3.40	3.86	......
	Hassall	1	31.37	36.58	27.66	......	4.39	......
	Muter	1	28.60	30.70	35.60	1.08	4.02	.75
	Patrick (2)	1	32.97	39.03	23.19	......	3.24	......
	Voelcker	2	32.18	37.36	24.31	2.22	3.93	.89
			20.27	43.98	33.55	......	2.20	.29
Swiss—American	Arnold	1	38.51	24.84	32.02	......	4.70	......
	Haecker	3 [c]	41.43	29.93	22.13	2.90	3.34	......
			35.91	33.21	24.82	3.32	3.06	......
			38.40	32.40	22.88	3.24	3.48	......
	Johnson	1	33.79	33.25	26.12	1.77	5.07	1.85
Swiss—Russian	Kalantarow	5 Average	32.74	32.26	24.85	4.43	5.78	2.67
		Maximum	35.44	37.20	28.81	6.90	7.44	4.78
		Minimum	29.80	28.97	20.57	.57	4.36	1.45
Swiss—Swedish	Dahl	3	29.34	36.44	23.20	6.11	4.78	......
			38.64	29.13	23.21	4.36	4.39	......
			36.02	32.05	24.76	4.59	2.39	......
Tessel	Mayer	1	54.40	18.30	20.10	1.40	5.80	3.40

[a] From cow's milk. [b] From sheep's milk. [c] Green cheese.

Analyses of cheese—Continued.

Variety.	Authority.	Number of analyses.	Water.	Fat.	Proteids, amids, etc.	Milk sugar, lactic acid, etc.	Total ash.	Salt in ash.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Thenay	Blin	1	30.14	15.00	18.12	....	6.10	4.80
Topfen	König	1	72.44	6.22	16.91	3.07	1.86	....
	Rubner	1	60.27	7.33	24.84	3.54	4.02	....
Trappist	Adametz	1	45.90	26.10	23.30	....	4.00	....
Troyes	Lindet	1	58.70	18.60	14.60	....	4.80	3.70
Vacherin	Benecke	1	54.02	23.74	18.98	2.04	3.08	1.77
	Lindt	1	45.87	27.21	25.29	....	1.63	....
Vendôme	Fallot	6 Average	48.69	20.90	27.97	....	4.43	2.79
		Maximum	56.33	30.61	45.52	....	5.58	3.68
		Minimum	29.63	10.80	17.74	....	3.10	2.08
Viterbo	Sartori	1	28.50	30.98	34.19	....	6.38	5.08
Vorarlberg	Eugling	9 Average	42.99	17.02	31.19	3.79	4.94	....
		Maximum	56.85	31.99	40.11	7.21	6.89	....
		Minimum	32.92	2.82	25.65	1.81	3.79	....
	von Klenze	2	56.61	4.48	36.42	....	2.49	....
			50.58	4.56	42.37	....	2.49	....
Warwickshire	Voelcker	3	31.97	29.08	27.43	7.16	4.86	.72
			33.61	30.04	29.70	1.95	5.60	2.78
			33.53	30.89	28.19	2.84	4.55	1.12
Wensleydale	Chattaway	1	28.30	33.30	27.20	....	3.70	....
Wiltshire	Griffiths	1	37.23	27.82	26.52	3.88	4.55	....
	Jones	1	36.34	28.00	31.12	....	4.41	....
	Voelcker	3	34.44	28.71	29.00	3.60	4.25	1.03
			39.22	19.26	34.22	2.28	5.02	.60
			40.07	25.56	26.81	2.24	5.33	1.41
Ziger	Eugling	3	68.51	3.15	22.13	3.97	2.31	....
			74.74	4.33	14.99	3.93	2.02	....
			68.47	5.22	18.72	3.97	3.62	....
	von Klenze	1	31.00	3.48	64.62	....	.90	....

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 147.
A. D. MELVIN, CHIEF OF BUREAU.

FATTENING CALVES IN ALABAMA.

INVESTIGATIONS IN COOPERATION WITH THE
ALABAMA AGRICULTURAL EXPERIMENT STATION.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., January 30, 1912.

Sir: I have the honor to transmit, and to recommend for publication as a bulletin of this bureau, a manuscript entitled "Fattening Calves in Alabama," by Prof. Dan T. Gray, of the Alabama Agricultural Experiment Station, and Mr. W. F. Ward, of the Animal Husbandry Division of this bureau.

The paper gives the details of three experiments in fattening calves in Alabama, two lots being fed during the winter on separate farms with various southern feeds, and the third lot carried through the winter and subsequently fattened while on pasture. These experiments form a part of the investigations in beef production which are being carried on by cooperation between the Alabama Experiment Station and this bureau, the work on the part of the bureau being under the direction of Mr. George M. Rommel, chief of the Animal Husbandry Division.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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FATTENING CALVES IN ALABAMA.

INTRODUCTION.

The beef-cattle business can be, and usually is, divided into two parts—breeding and fattening. As a rule, the man who raises the calf does not finish it on his own farm for the market; he usually sells it to a neighboring farmer who makes a business of fattening and preparing the calf or steer for the market. Thus the feeder oftentimes has no interest at all in raising the calves. Probably the ideal condition, at least for Alabama and adjacent States, is for the calf to be raised and finished on the same farm. But this ideal condition can seldom be realized because the man who raises the calf has, as a rule, only a few cows and can seldom afford to take the time and trouble to fatten the few calves which these cows bring each year. Even if the small farmer were to fatten these few calves each year he could seldom afford to ship them to the larger markets, so he is at the mercy of the local buyers. As a result of this condition of affairs the professional feeder has developed. His business is to collect calves and steers into carload lots and prepare them for the open market.

The farmer who has as many as 30 breeding cows on his farm should make it a rule to fatten their offspring himself; he can seldom afford to sell the calves to the professional feeder. The feeder usually makes money on the process of fattening, and the man who raises calves in sufficient numbers should keep this extra profit at home. Furthermore, the farmer who has from 8 to 12 calves or steers ready for the feed lot will usually find it profitable to buy a sufficient number of feeders to complete the load, and he can then finish all of them on his own farm.

There are many ways of disposing of beef calves or cattle, and the farmer should be watchful and avoid methods by which money might be lost. It is possible to raise beef cattle properly and by selling them improperly to lose money on the business, in just the same way that it is possible to raise good apples, potatoes, and peaches and lose money on them when the marketing part of the business is not studied and given proper attention. When beef cattle are bred, fed, and marketed in a scientific and businesslike manner, satisfactory profits should be realized. This is proved by the experience of good cattlemen, and by the cooperative experimental work between the Bureau of Animal Industry and the Alabama Experiment Station.

PLAN OF THE WORK.

The farmer who raises calves is often at a loss to know at what age they should be disposed of. The spring calf may be sold the subsequent fall; it may be fattened during the winter months and sold as a fat yearling calf; it may be kept on the farm until it is from 2 to 4 years of age and then sold to a professional feeder; or, the mature steer may be fattened on the farm where it was raised instead of being sold to a feeder. On account of these various methods which it is possible to adopt for disposing of beef animals, the owner is often in doubt as to the most profitable manner of handling and disposing of his crop of calves.

This bureau, working in cooperation with the Alabama Experiment Station, has done several years' experimental work in fattening mature steers for the market.[1] The steers used in these experiments were not raised on the farm where they were fattened; they were purchased from small farmers who sold them for from 2½ to 3½ cents a pound, the price paid depending upon the quality, age, size, and condition of the animals. Excellent profits were realized on all of these cattle with the exception of one lot, but it is probable that some of the farmers who raised the steers lost money on their part of the transaction, as cattle can not be raised and sold at a profit for 2½ cents a pound.

Since the publication of the results of the work above mentioned, many farmers in the South have raised the question, "Why not fatten the animals while they are young?" In the past the farmers and planters insisted on keeping the offspring of their beef cows until they were from 3 to 4 years old, but many inquiries are now made as to the advisability of fattening the calves so as to dispose of them by the time they are a year old.

Two or three points can be urged in favor of this system. First, more breeding animals can be kept upon a farm when the offspirng. are disposed of at an early age, than when they are held and sold as steers. Second, the younger the animal, the cheaper each pound of beef is made. Third, the money invested is turned more rapidly when the calves are sold at a young age.

In order that they might be in a position to assist in answering such inquiries, authorities of the Bureau of Animal Industry and the Alabama Experiment Station undertook three experiments in fattening calves, which are hereafter described. The details in this bulletin are accordingly divided into three parts. In Part I the calves were fattened, during their first winter, on cottonseed meal and hulls, corn-and-cob meal, and alfalfa hay; in Part II similar winter fattening was carried on with cottonseed meal and hulls and peavine hay, and in Part III the calves were fed in the winter and fattened during the following pasture season.

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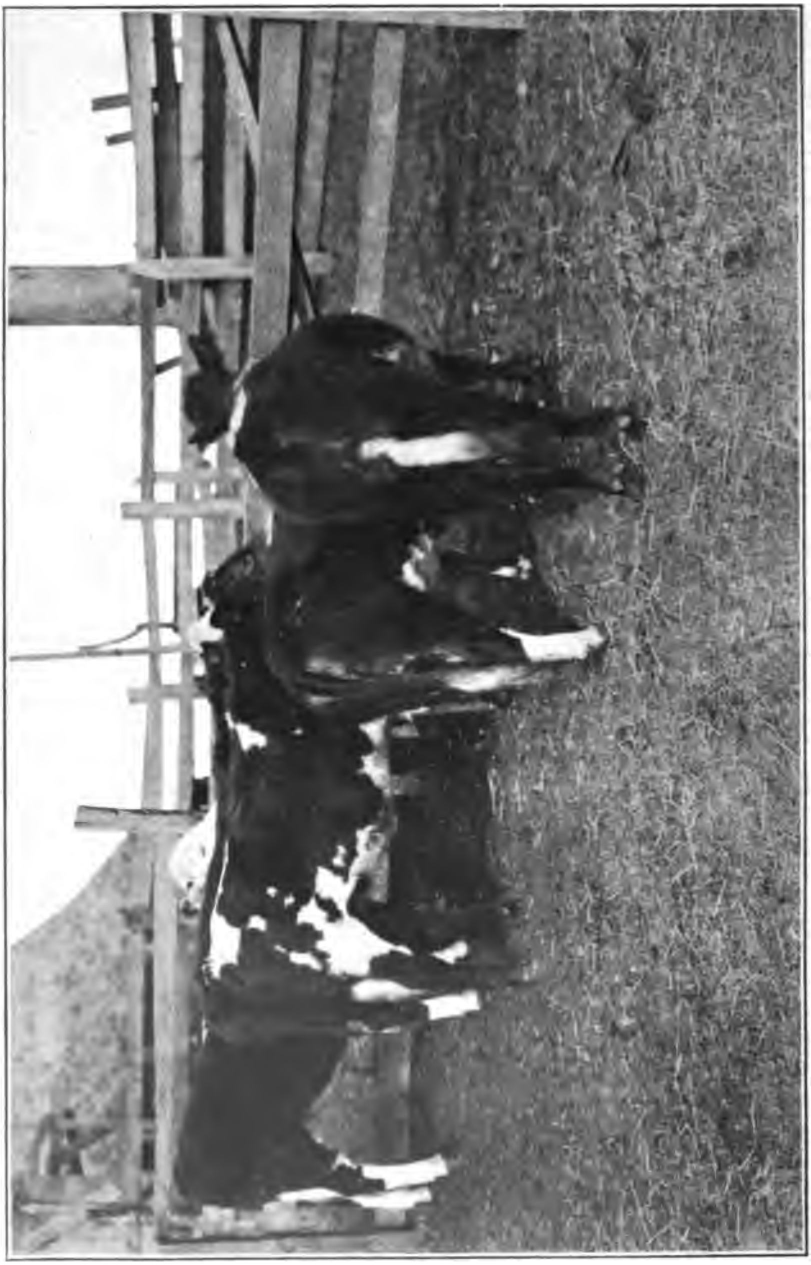
[1] See Bureau of Animal Industry Bulletins 103 and 131, and Alabama Experiment Station Bulletins 150 and 151.

CALVES USED IN FEEDING EXPERIMENTS. LOT 3 (PART I) AT BEGINNING OF TEST.

PLATE II.



CALVES AFTER WINTER FATTENING. LOT 2 (PART 1) AT CLOSE OF TEST.

I. WINTER FATTENING OF CALVES ON COTTONSEED MEAL AND HULLS, CORN-AND-COB MEAL, AND ALFALFA HAY.

The main object in doing this calf-feeding work was to determine whether the farmer can afford to raise a good grade of calves and finish them for the market while they are yet less than a year old. Secondary considerations were, of course, involved as well.

In this part of the test the calves were divided into three lots, so that a comparison of certain feeds could be made. The following problems were studied:

1. To learn whether a farmer can profitably raise and fatten calves and finish them for the market by the time they are a year old.
2. To make comparisons of southern feeds and combinations of feeds which can be used for fattening calves during the winter months.

Owing to the fact that a high grade of calves can not be obtained near the Experiment Station at Auburn, Ala., the work was carried on upon the farm of Messrs. Cobb and McMillan, of Sumterville, Ala., with whom the bureau and the station have been in cooperation for a number of years. Messrs. Cobb and McMillan furnished the calves and the feed, and the bureau and the Experiment Station provided a trained man to live on the farm and have personal supervision of the experimental work. Mr. H. J. Chatterton was stationed upon the farm and supervised the work.

KIND OF CALVES USED.

The calves used in this work were high-grade animals. The farmer who raises beef cattle can not afford to raise scrubs, especially the man who expects to finish them for the market while they are young. It would have been absolutely impossible to have made a profit on these calves if they had been scrubs instead of high-grade beef calves. High-priced feeds can seldom be fed profitably to low-priced cattle. It may be possible for a professional feeder to make a profit on scrubs even when high-priced feeds are used, but when such is the case it means that the feeder made the profit at the expense of the man who raised the scrubs. In other words, it means that the feeder did not pay the producer as much for the scrubs as it actually cost to raise them.

The majority of the calves were raised on the farm of Cobb and McMillan, near Sumterville, Ala., where the feeding was done. Some of them were purchased from neighboring farmers in Sumter and adjoining counties. The calves were all well-bred animals, although not purebred. They were grade Shorthorns, Aberdeen-Angus, Herefords, and Red Polls, the majority being from one-half to seven-eighths pure. All had been born the preceding spring, so they were from 6 to 8 months of age when the fattening experiment began. During the summer they had run with their mothers on good pasture, and during this time they demanded practically no attention from the owner, except to see that they were salted and dipped. Both the mothers and the calves were dipped regularly all through the summer months to reduce the number of ticks. Very few ticks appeared on the cattle during the summer time.

On November 17, 1910, when the preliminary feeding began, the calves averaged 338 pounds in weight

GENERAL PLAN OF THE WORK.

When fall arrived and the pastures were exhausted the calves were taken from their mothers and placed in this winter work. They were in excellent condition at this time. The original intention had been to begin the winter feeding early in the fall, to avoid losing any part of the calf fat, but on account of an unavoidable delay the feeding was not begun until the above-mentioned date, so no doubt the calves lost a few pounds in weight after the pastures became short.

On November 17, 1910, the calves were tagged, dehorned, and divided into three lots. Each lot was fed until March 17. 1911, on the following feeds:

Lot 1. Cottonseed meal, cottonseed hulls, mixed alfalfa hay. Lot 2. Cottonseed meal, two-thirds; corn-and-cob meal, one-third; cottonseed hulls; mixed alfalfa hay. Lot 3. Cottonseed meal, one-third; corn-and-cob meal, two-thirds; cottonseed hulls; mixed alfalfa hay.

SHELTER AND LOTS.

The calves were young, so each lot was provided with shelter sufficiently good to turn the cold rains and break the cold north winds. If they had been mature steers the shelter would not have been necessary, but calves will not do well, even this far south, without some protection from the cold winds and rains of the winter months. Each lot was confined in a one-half acre paddock. While the lots were not paved, still they did not become excessively muddy, even during the periods of excessive rain. The ground floors of the sheds were always dry, so the calves had a comfortable and convenient place in which to rest.

METHOD OF FEEDING AND HANDLING THE CALVES.

On November 17, 1910, all the calves were tagged and dehorned. On the following day the individual weights were secured and the 77 calves were divided into three lots as nearly equal as possible in quality, weight, and breeding. The preliminary feeding began November 18, 1910. All of the males were castrated on November

23 and 24. No doubt the results would have been more satisfactory if the calves had been castrated at an earlier age.

The animals were fed twice each day, the morning feed being given about 7 o'clock and the night feed at 5 o'clock. The concentrated feeds were placed in the troughs, each of which was about 12 feet long and 3 feet wide. The hay was fed in separate hay racks. Both the troughs and the racks were under sheds so that the feed never became wet and the calves had comfortable quarters in which to eat. Salt was supplied regularly, also good pure water in clean troughs.

At the beginning and end of the experiment individual weights were taken on two successive days. During the course of the test the total weight of each lot was taken every 28 days.

CHARACTER AND PRICE OF FEEDS.

Cottonseed meal, corn-and-cob meal, cottonseed hulls, and mixed alfalfa hay were all used in this test. The cottonseed meal and the hulls were purchased and hauled to the farm. The corn-and-cob meal and the mixed alfalfa hay were grown upon the farm. All of the feeds were of good quality. The cottonseed meal was fresh and bright; the hay consisted of a mixture of about one-half each of Johnson grass and alfalfa. The corn was grown upon the farm, and before it was fed the whole ear of corn with the shuck was run through a grinder and made into corn-and-cob meal.

The feeds were valued as follows:

Cottonseed meal	per ton	$26.00
Cottonseed hulls	do	7.00
Corn	per bushel	.70
Mixed hay	per ton	15.00

As a matter of fact the cottonseed meal cost only $25 a ton, and corn was worth only 50 cents a bushel, but the above prices were adopted for the sake of uniformity. These prices have been used in other publications of this bureau, and represent fairly accurately the average prices of feeds in this State

DAILY RATIONS.

More care and skill must be exercised in feeding a young animal than an old one. A 6-year-old ox may be cared for and fed in a careless manner and still no serious results follow; but the young calf will not grow and develop with any degree of satisfaction under a careless system of management and feeding. The younger the animal the greater the skill required to care for and feed it; one case of overfeeding will often throw the stomach and bowels out of condition for weeks.

It will be noticed from the table below that at first the calves were given a very small quantity of concentrated feed, the amount being gradually increased to the end of the test. They were given, from the beginning, all of the hay they would clean up.

TABLE 1.—*Daily ration for each calf (November 17, 1910, to March 17, 1911).*

Period.	Lot 1.			Lot 2.				Lot 3.			
	Cotton-seed meal.	Cotton-seed hulls.	Mixed hay.	Cotton-seed meal.	Corn-and-cob meal.	Cotton-seed hulls.	Mixed hay.	Cotton-seed meal.	Corn-and-cob meal.	Cotton-seed hulls.	Mixed hay.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
November 17 to December 7 (preliminary period)	2.09	5.34	5.10	1.91	0.69	5.77	5.57	1.36	1.69	5.35	4.66
December 8 to January 4 (28 days)	2.69	7.36	5.05	1.85	.92	7.36	5.18	1.85	3.73	7.39	3.70
January 5 to February 1 (28 days)	3.16	7.57	5.24	2.14	1.17	7.57	5.51	2.14	4.67	7.57	3.36
February 2 to March 1 (28 days)	3.63	8.00	5.86	2.70	1.35	8.00	5.51	2.15	4.30	8.00	3.57
March 2 to March 17 (16 days)	3.67	8.88	5.79	3.42	1.71	8.80	5.74	2.00	4.00	8.00	5.60

During the preliminary feeding period each calf in lot 1 received an average of only 2.09 pounds of cottonseed meal each day, and during the last 16 days of the feeding period the calves in this lot received an average daily feed of only 3.67 pounds of cottonseed meal. At one time the daily allowance was raised to 4 pounds for each calf, but some of them began to scour and the allowance of meal was quickly reduced. The calves in lots 2 and 3 received a partial feed of corn-and-cob meal; this was mixed with the cottonseed meal, so the daily allowance of concentrated feeds for the calves of these two lots was greater than that of the calves in lot 1. During the preliminary period each calf in lot 2 received a daily feed of 2.6 pounds of concentrated feeds, practically one-fourth of the amount being corn-and-cob meal. Each calf in lot 3, during the same period, received 3.05 pounds daily of the concentrated feeds, 55.4 per cent of which was corn-and-cob meal. At the end of the test each calf in lot 3 was eating 6 pounds daily of a mixture of one-third cottonseed meal and two-thirds corn-and-cob meal. They ate this amount readily with no ill results following.

It should be noted that when the amount of feed was increased it was increased gradually. No abrupt changes were made.

WEIGHTS AND GAINS.

When the preliminary weights were taken, November 18, 1910, the calves averaged from six to eight months in age. While they were not large for their age, they were larger than the average for the State. Their mothers probably averaged about 1,000 pounds in weight in usual breeding condition. The calves had not been pampered in any way during the summer months; they had simply run with their mothers upon a reasonably good pasture.

In some previous experimental work done by this bureau and the Alabama Experiment Station, yearling grade Angus calves attained a weight of only 402 pounds, but they were heavily infested with ticks. Some ticks were permitted to get on the calves used in the present test, but they were not badly infested. Of course, this slight infestation retarded their development, but just how much it is impossible to state.

The table below shows that the calves made satisfactory gains during the winter feeding periods.

TABLE 2.—*Weights, total gains, and average daily gains.*

PRELIMINARY PERIOD (NOV. 17 TO DEC. 7).

Lot.	Number of calves.	Ration.	Number of days fed.	Average initial weight of each calf.	Average final weight of each calf.	Average total gain of each calf.	Average daily gain of each calf.
				Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1	27	Cottonseed meal Cottonseed hulls Mixed alfalfa hay	19	338	380	42	2.21
2	24	Cottonseed meal, two-thirds Corn-and-cob meal, one-third Cottonseed hulls Mixed alfalfa hay	19	333	374	41	2.16
3	26	Cottonseed meal, one-third Corn-and-cob meal, two-thirds Cottonseed hulls Mixed alfalfa hay	19	328	367	39	2.05

REGULAR FEEDING PERIOD (DEC. 8, 1910, TO MAR. 17, 1911).

1	27	Cottonseed meal Cottonseed hulls Mixed alfalfa hay	100	380	541	161	1.61
2	24	Cottonseed meal, two-thirds Corn-and-cob meal, one-third Cottonseed hulls Mixed alfalfa hay	100	374	543	169	1.69
3	26	Cottonseed meal, one-third Corn-and-cob meal, two-thirds Cottonseed hulls Mixed alfalfa hay	100	367	546	179	1.79

PRELIMINARY AND REGULAR PERIODS COMBINED (NOV. 17, 1910, TO MAR. 17, 1911).

1	27	Cottonseed meal Cottonseed hulls Mixed alfalfa hay	119	338	541	203	1.71
2	24	Cottonseed meal, two-thirds Corn-and-cob meal, one-third Cottonseed hulls Mixed alfalfa hay	119	333	543	210	1.76
3	26	Cottonseed meal, one-third Corn-and-cob meal, two-thirds Cottonseed hulls Mixed alfalfa hay	119	328	546	218	1.83

During the preliminary period from November 17 to December 7 the calves were dehorned and the males castrated, yet they made excellent gains. The lots gained a daily average of 2.21, 2.16, and 2.05 pounds, respectively, during this period. Of course some of this increase can be attributed to "fill"; it was not all real gain in terms of meat and bone.

During the regular experiment from December 8 to March 17 the gains were also entirely satisfactory. The calves in lot 1, the lot which had no corn-and-cob meal mixed with cottonseed meal, made the smallest gains, each calf gaining 1.61 pounds a day; this, however, was a satisfactory daily gain for small and young animals. The calves in lot 3, the lot which was given the heavy feed of corn-and-cob meal along with the cottonseed meal, made the greatest gains, each calf gaining 1.79 pounds daily. The calves in lot 2, the lot which received the small amount of corn-and-cob meal along with the cottonseed meal, made an average daily gain of 1.69 pounds.

During the whole winter feeding period each calf gained an average of 203, 210, and 218 pounds in weight in lots 1, 2, and 3, respectively, so that when the calves were sold, March 17, the whole lot of 77 calves averaged 543 pounds in weight. They were practically 12 months old when sold.

It should not be inferred that the ration which produced the greatest gain in a given time is necessarily the best or most profitable one. While the question of rapidity of gain is an extremely important factor in final profits, there are other factors, as the cost of the gain, which must be taken into consideration.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS GAIN.

While the feeds used were all expensive ones, the cost to make 100 pounds of gain in live weight was not excessive. In fact, the gains were made cheaply. This was due to several factors. First, the calves were young and growing, and young animals of all kinds can be made to increase in weight more economically than old ones. Second, the calves were very thrifty, and so made good use of the feed that they ate. Third, all of the rations were extremely palatable, especially the two which had the corn-and-cob meal mixed with the cottonseed meal. A young animal of any kind will not make satisfactory gains on an unpalatable ration. Fourth, the calves had comfortable quarters and were fed and watered regularly.

TABLE 3.—*Quantity and cost of feed required to make 100 pounds of gain.*

Lot.	Ration.	Preliminary period—19 days (Nov. 17 to Dec. 7).		Regular feeding period—100 days (Dec. 8 to Mar. 17).		Preliminary and regular periods combined—119 days (Nov. 17 to Mar. 17).	
		Pounds of feed to make 100 pounds of gain.	Cost of feed to make 100 pounds of gain.	Pounds of feed to make 100 pounds of gain.	Cost of feed to make 100 pounds of gain.	Pounds of feed to make 100 pounds of gain.	Cost of feed to make 100 pounds of gain.
		Pounds.	*Dollars.*	*Pounds.*	*Dollars.*	*Pounds.*	*Dollars.*
1	Cottonseed meal	95	3.80	201	6.85	179	6.22
	Cottonseed hulls	241		486		435	
	Mixed alfalfa hay	230		338		315	
2	Cottonseed meal, two-thirds	88	4.40	143	6.63	133	6.19
	Corn-and-cob meal, one-third	40		72		65	
	Cottonseed hulls	266		464		425	
	Mixed alfalfa hay	257		323		310	
3	Cottonseed meal, one-third	66	4.51	114	6.95	130	6.83
	Corn-and-cob meal, two-thirds	103		234		211	
	Cottonseed hulls	261		430		400	
	Mixed alfalfa hay	228		216		218	

During the preliminary period the calves made both rapid and economical gains, notwithstanding the fact that they had been dehorned and castrated. It cost $3.80, $4.40, and $4.51 to make 100 pounds of gain in live weight in lots 1, 2, and 3, respectively, during the preliminary period. In this period, therefore, the calves which ate nothing except cottonseed meal, hulls, and alfalfa hay made the cheapest gains. This, however, was not true of the test when taken as a whole.

After the calves had been on feed some weeks, with the "fill" not taken into consideration, the gains were not made as cheaply as at first. Under average feeding conditions the cheapest gains are made during the first few weeks of the fattening process; the expensive gains are usually made near the close of the feeding period. During the regular feeding period it cost $6.85, $6.63, and $6.95 to make 100 pounds of gain in lots 1, 2, and 3, respectively. The cheapest gains were by the calves in lot 2, where the small amount of corn-and-cob meal was fed along with the cottonseed meal. The most expensive gains were made in lot 3, where the calves received a heavy proportion of corn-and-cob meal.

The cost of the gains, however, does not determine absolutely the final profits. While the cost of the gains is a very important factor in determining final profits, there are other factors which must be taken into consideration as well. The final selling price of the cattle must also be considered as an important factor. If expensive gains are accompanied by a proportionate increase in the final value and selling price of the cattle, the cost of the gains is a minor consideration; but if expensive gains do not increase the final selling price of the animal in proportion to the increased expense of making the gains, those feeds which have caused the expensive gains should be eliminated.

When the preliminary and the regular periods are combined into one period of 119 days, it cost $6.22, $6.19, and $6.83 to produce 100 pounds of gains in lots 1, 2, and 3, respectively, lot 2 still showing up to the best advantage and lot 3 to a considerable disadvantage.

PRICES REALIZED ON EACH KIND OF FEED WHEN PRICES OF THE OTHER FEEDS ARE FIXED.

As previously stated, the cottonseed meal cost $26 a ton and the hulls $7 a ton, the hay being valued at $15 a ton and the corn at 70 cents a bushel. Before a farmer spends $26 for a ton of cottonseed meal and $7 for a ton of hulls to be used as a feed for cattle he should know whether or not he will get his money back in the shape of profits on the cattle. In other words, the farmer should know whether he will be able to realize a profit on the money invested in the feed. When he has hay and corn on his farm he expects to sell them at the highest possible price. When, in addition, he has cattle the farmer often hesitates as to the best method of disposing of the corn and hay. The question arises in his mind, Should I feed the hay and corn to the calves and steers, or should I sell these feeds directly upon the market?

The following table throws some light on this problem:

Table 4.—*Prices realized on each feed when fed to the calves and prices of the other feeds are fixed.*

Feed.		Lot 1.	Lot 2.	Lot 3.
Cottonseed meal	per ton	$36.10	$42.18	$36.50
Cottonseed hulls	do	11.15	12.05	10.40
Corn	per bushel	....	1.90	.95
Alfalfa hay	per ton	20.72	20.92	21.25

While the cottonseed meal cost only $26 a ton, it was fed to the calves and sold, by means of them, for $36.10 to $42.18 a ton. The hulls cost only $7 a ton, and they were resold, by means of the calves, for $10.40 to $12.05 a ton. If the corn had been sold upon the market it would not have brought more than 60 cents a bushel during the fall of 1910 (it is charged against these calves, however, at 70 cents a bushel), but when it was fed to these calves it was sold, by means of the calves, for 95 cents a bushel in lot 3 and $1.90 a bushel in lot 2. If the mixed alfalfa hay had been sold as hay, it would not have brought more than $15 a ton on the farm, but it was sold, through the calves, for $20.72 to $21.25 a ton.

These results tend to show that the farmer can usually afford to buy certain outside feeds—feeds which have not been grown on the farm—for feeding his animals, while he can almost always afford to feed his home-grown feeds to live stock rather than sell them upon the market.

FINANCIAL STATEMENT.

These calves were raised on the farm on which they were fattened, so the initial or fall price is an estimated one. Their estimated value was placed at 3½ cents a pound on the farm, without shrink, when these experiments began, November 17, 1910.

When they were ready to be sold, buyers visited the farm to make bids. At the time of sale the beef market was on a rapid decline, so they did not sell as well as was expected. They were sold March 17, 1911, the calves in lot 1 selling for $5.01 per hundredweight on the farm, those in lot 2 bringing $5.11 per hundredweight, and those in lot 3 selling for $5.26 per hundredweight. All the sales were based on the farm weight after a 3 per cent shrink. They were shipped to the Cincinnati market, where complete slaughter records were secured.

TABLE 5.—*Financial statement.*

Lot 1. Cottonseed meal, cottonseed hulls, mixed alfalfa hay:		
By sale of 27 calves, 14,172 pounds, at $5.01 per hundredweight		$710.02
To 27 calves, 9,120 pounds, at 3½ cents a pound	$319.20	
To 9,821 pounds cottonseed meal, at $26 a ton	127.67	
To 23,908 pounds cottonseed hulls, at $7 a ton	83.68	
To 17,320 pounds mixed alfalfa hay, at $15 a ton	129.90	
Total expense		660.45
Total profit		49.57
Profit per calf		1.84
Lot 2. Cottonseed meal two-thirds, corn-and-cob meal one-third, cottonseed hulls, mixed alfalfa hay:		
By sale of 24 calves, 12,633 pounds, at $5.11 per hundredweight		$645.55
To 24 calves, 7,984 pounds, at 3½ cents a pound	$279.44	
To 6,682 pounds cottonseed meal, at $26 a ton	86.87	
To 3,298 pounds corn-and-cob meal, at 70 cents a bushel	32.98	
To 21,418 pounds cottonseed hulls, at $7 a ton	74.96	
To 15,630 pounds mixed alfalfa hay, at $15 a ton	117.23	
Total expense		591.48
Total profit		54.07
Profit per calf		2.25
Lot 3. Cottonseed meal one-third, corn-and-cob meal two-thirds, cottonseed hulls, mixed alfalfa hay:		
By sale 26 calves, 13,774 pounds, at $5.26 per hundredweight		$724.51
To 26 calves, 8,531 pounds, at 3½ cents a pound	$298.59	
To 7,353 pounds cottonseed meal, at $26 a ton	95.59	
To 11,963 pounds corn-and-cob meal, at 70 cents a bushel	119.63	
To 22,687 pounds cottonseed hulls, at $7 a ton	79.40	
To 12,363 pounds mixed alfalfa hay, at $15 a ton	92.72	
Total expense		685.93
Total profit		38.58
Profit per calf		1.48

The foregoing shows that all of the calves were fed at a profit, the lowest being $1.48 per calf in lot 3 and the highest $2.25 per calf in lot 2. What do these profits mean? They mean that the corn and hay raised on the farm were sold, through the calves, at 70 cents a bushel and $15 a ton, respectively; that the money expended for cottonseed meal and hulls was all returned to the owner; that the fertilizer value of these feeds was left on the farm, and, in addition, each calf returned the above additional profits. The monetary returns were satisfactory, as the farm feeds were sold for more, by means of the calves, than could have been secured for them on the market, and their fertilizing value was left on the farm in the shape of barnyard manure.

The calves in lot 3, the ones which received the heavy ration of corn-and-cob meal, returned the smallest profit, notwithstanding the fact that they sold for the highest price at Cincinnati. The increase in the price did not overcome the added expense of feeding a heavy ration of corn-and-cob meal. While it did not pay to feed the heavy ration of corn-and-cob-meal, it did pay to feed the small amount of corn-and-cob meal which was used in lot 2, as the calves in this lot proved to be the most profitable ones fed. This indicates that when fattening beef calves with cottonseed meal and corn-and-cob meal as concentrates one-third of the concentrated part of the ration can profitably consist of corn-and-cob meal, while it is less profitable to have corn-and-cob meal constitute two-thirds of the concentrated part of the ration.

However, there is one factor that has not been taken into consideration which, if considered, would add to the profits of lots 2 and 3, especially the latter. Some undigested corn passed through the calves in these two lots; if hogs followed them they would derive no little benefit from the droppings. In fact, several hogs did follow the calves in lot 3, but no record was kept of their gains. These gains should be credited to the calves.

SLAUGHTER RECORDS.

As stated before, these calves were all shipped to the Cincinnati market, where full slaughter data were secured. The animals were driven 9 miles from the farm to the railroad, and on account of unusual delays they were on the cars 67 hours before reaching Cincinnati. The slaughter results are given in the following table:

TABLE 6.—*Slaughter data.*

Lot.	Number of calves.	Live weights.			Shrinkage.		Per cent dressed.	
		Total on farm.	On farm after 3 per cent shrink.	At Cincinnati.	Total.	Average per calf.	By shrunk farm weight.	By market weight.
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*
1	27	14,610	14,172	13,050	1,560	57.8	47.6	51.7
2	24	13,024	12,633	11,740	1,284	53.5	47.8	51.5
3	26	14,200	13,774	12,700	1,500	57.7	48.9	53.1

The calves of lot 3, the ones which received the large proportion of corn-and-cob meal, dressed out the highest, each calf in this lot dressing 53.1 per cent of the market weights. The calves in lots 1 and 2 dressed out 51.7 and 51.5 per cent, respectively.

The trip was a hard one on the calves, and when the size of the animals is taken into consideration they shrank heavily on the road to Cincinnati. The average loss in weight for each calf was 57.8 pounds in lot 1, 53.5 pounds in lot 2, and 57.7 pounds in lot 3.

SUMMARY.

The first experiment is summarized as follows:

TABLE 7.—*Summary statement.*

Item.	Lot 1.	Lot 2.	Lot 3.
Calves in each lot	27	24	26.
Ration	Cottonseed meal Cottonseed hulls Mixed alfalfa hay	Cottonseed meal, two-thirds. Corn-and-cob meal, one-third. Cottonseed hulls Mixed alfalfa hay	Cottonseed meal, one-third. Corn-and-cob meal, two-thirds. Cottonseed hulls. Mixed alfalfa hay.
Total days fed	119	119	119.
Average weight when feeding began.	338 pounds	333 pounds	328 pounds.
Average final weight	541 pounds	543 pounds	546 pounds.
Average gain of each calf	203 pounds	210 pounds	218 pounds.
Average daily gain of each calf.	1.71 pounds	1.76 pounds	1.83 pounds.
Pounds feed to make 100 pounds gain.	179 pounds meal 435 pounds hulls 315 pounds hay	133 pounds meal 65 pounds corn 425 pounds hulls 310 pounds hay	130 pounds meal. 211 pounds corn. 400 pounds hulls. 218 pounds hay.
Cost to make 100 pounds gain.	$6.22	$6.19	$6.83.
Price realized on each ton of cottonseed meal when other prices are fixed.	$36.10	$42.18	$36.50.
Price realized on each ton of hulls when other prices are fixed.	$11.15	$12.05	$10.40.
Price realized on each bushels of corn when other prices are fixed.		$1.90	$0.95.
Price realized on each ton of hay when other prices are fixed.	$20.72	$20.92	$21.25.
Fall price of calves per cwt.	$3.50	$3.50	$3.50.
Selling price of calves per cwt.	$5.01	$5.11	$5.26.
Profit on each calf above all expenses.	$1.84	$2.25	$1.48.

1. The animals used in the experiment were calves ranging from 6 to 8 months in age.

2. The feeding was begun November 17, 1910, and continued until March 17, 1911.

3. The 77 calves were divided into three lots and each lot fed upon the following feeds:

Lot 1. Cottonseed meal; cottonseed hulls; mixed alfalfa hay. Lot. 2. Cottonseed meal, two-thirds; corn-and-cob meal, one-third; cottonseed hulls; mixed alfalfa hay. Lot 3. Cottonseed meal, one-third; corn-and-cob meal, two-thirds; cottonseed hulls; mixed alfalfa hay.

4. During the whole feeding period each calf in lots 1, 2, and 3 made an average daily gain of 1.71, 1.76, and 1.83 pounds, respectively.

5. When the whole feeding period is taken into consideration the following pounds of feed were required to make 100 pounds of gain:

Lot 1: 179 pounds of cottonseed meal, 435 pounds of hulls, and 315 pounds of hay. Lot 2: 133 pounds of cottonseed meal, 65 pounds of corn-and-cob meal, 425 pounds of hulls, and 310 pounds of hay.

Lot 3: 130 pounds of cottonseed meal, 211 pounds of corn-and-cob meal, 400 pounds of hulls, and 218 pounds of hay.

6. When the whole feeding period is taken into consideration, each 100 pounds of gain in lots 1, 2, and 3 cost $6.22, $6.19, and $6.83, respectively.

7. Cottonseed meal cost $26 a ton, but, by means of the calves, was sold for $36.10, $42.18, and $36.50 a ton in lots 1, 2, and 3, respectively, when the prices of the other feeds were fixed.

8. Cottonseed hulls cost $7 a ton, but, by means of the calves, each ton was sold for $11.15, $12.05, and $10.40 in lots 1, 2, and 3, respectively, when the prices of the other feeds were fixed.

9. By means of the calves each bushel of corn was sold for $1.90 and $0.95 in lots 2 and 3, respectively, when the prices of the other feeds were fixed.

10. By means of the calves each ton of alfalfa hay was sold for $20.72, $20.92, and $21.25 in lots 1, 2, and 3, respectively, when the prices of the other feeds were fixed.

11. The calves cost $3.50 per hundredweight at the beginning of the test. At the close they sold for $5.01, $5.11, and $5.26 per hundredweight in lots 1, 2, and 3, respectively.

12. Each calf netted a clear profit of $1.84, $2.25, and $1.48 in lots 1, 2, and 3, respectively.

13. The profits were satisfactory, as the farm crops were sold for considerably more, by means of the calves, than if they had been sold as farm crops, and the value of the fertilizer should also be considered.

II. FATTENING CALVES IN WINTER ON COTTONSEED MEAL, COTTONSEED HULLS, AND PEA-VINE HAY.

Fifty-two calves were used in the second experiment, the main objects of which were:

1. To determine whether or not young beef calves can be fattened profitably for the spring market on a feed of cottonseed meal, cottonseed hulls, and mixed pea-vine hay.
2. To study the value of shelter for young calves while being fattened.

The 52 calves were divided into two lots when the test began on December 7, 1910. One lot was fed under the shelter of a good barn, the other lot being fed in a corn-stalk field with no shelter at all except some trees. It was subsequently seen, however, that these young calves would not thrive during the winter months without a shelter to turn the cold rains, so on February 11, 1911, they were brought into the barns and placed under the sheds with the other calves. After February 11 the 52 head of calves were fed as one lot.

The work was done in cooperation with Mr. E. F. Allison, of Sumter County, Ala., who had kindly agreed to cooperate in experimental work with beef cattle and hogs. Mr. Allison furnished the calves and the feed, while the bureau and the experiment station provided a trained man to be stationed on the farm to look after the experiment. Mr. L. W. Shook lived on the farm and had personal charge of the work.

THE CALVES.

The majority of the calves used in this experiment were raised on the farm of Mr. Allison, near Bellamy, Ala. A few calves were purchased from neighbors. More than half of those raised on Mr. Allison's farm were grade Aberdeen-Angus of excellent quality. The ones which were purchased from neighbors were of common quality and showed very little beef blood. As a whole, they were not as large or as good in quality as were the calves which were used in the other two tests reported in this bulletin. When the test began they had attained an average weight of 313 pounds. The calves were born during the spring of 1910, so were from 6 to 8 months old when the test began, December 7, 1910. They were valued at 3 cents a pound at the beginning of the experiment.

PLAN OF THE WORK.

At the beginning of the test the 52 calves were divided into two lots of 26 each. One lot was fed in a small paddock, across the west side of which extended a good shelter. As previously stated, the intention at first was to feed the second lot of calves without shelter; that is, they were to be fed in a cornfield where no shelter, except trees, was available. All were started on feed December 7, 1910, but it was seen that the calves without shelter were not making satisfactory and economical gains, as the winter was unusually wet and cold, so on February 11, 1911, the field lot of calves was brought to the barn and placed with the other calves. The whole 52 head were fed together in one lot from February 11 to the end of the test, March 29, 1911.

On account of the fact that the two lots were finally thrown together into one, the test is presented in this publication as one lot.

PRICES AND QUALITY OF FEEDS.

Cottonseed meal, cottonseed hulls, and mixed cowpea hay were the feeds used. The cowpea hay was grown upon the farm; the other two feeds were purchased on the market. On March 20, 1911, the supply of cowpea hay was exhausted and a change was made to a rather poor quality of hay, composed of crab grass, with a small trace of Lespedeza and pea vines. The feeds were valued as follows:

Cottonseed meal	per ton	$26.00
Cottonseed hulls	do	7.00
Mixed pea-vine hay	do	15.00

DAILY RATIONS.

During the first month no hay was fed, but it was thought that it would be profitable to use some hay along with the hulls, so it was provided after the first month.

It should be remembered in studying the following daily feeds that these were young and small calves. Their average weight was only 313 pounds when the test began.

TABLE 8.—*Daily ration for each calf, by monthly periods, from Dec. 7, 1910, to Mar. 29, 1911.*

Period.	Cottonseed meal.	Cottonseed hulls.	Hay.
	Pounds.	*Pounds.*	*Pounds.*
First 28 days	2.84	10.20	0
Second 28 days	3.11	10.40	2.04
Third 28 days	3.27	9.94	2.04
Fourth 28 days	3.09	9.50	1.92

During no period did the calves average more than 3.27 pounds each of cottonseed meal daily. Even with this small allowance of the meal a few calves scoured. They were given a definite number of pounds of hulls along with the meal, and all of the hay they would eat up clean after each meal. They ate, on the average, practically 10 pounds of hulls per calf per day, and slightly more than 2 pounds of hay. Many feeders would criticise these rations as being too small, but satisfactory gains were made.

WEIGHTS AND GAINS.

The calves did not make unusually large gains, but when their size is taken into consideration it is seen that they increased in weight at a reasonable rate. The feeding period was continued for 112 days, and during this time an average daily gain of 1.24 pounds was secured.

TABLE 9.—*Weights and gains for total feeding period of 112 days, from Dec. 7, 1910, to Mar. 29, 1911.*

Number of calves.	Average initial weight of each calf.	Average final weight of each calf.	Average total gain of each calf.	Average daily gain of each calf.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
52	313	452	139	1.24

At the inauguration of the experiment each calf weighed 313 pounds; at the close they had attained an average weight of 452 pounds; hence, during the feeding period of 112 days (Dec. 7, 1910, to Mar. 29, 1911) each calf made a total gain of 139 pounds. The animals were thrifty throughout the whole test.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS GAIN.

Considering that these calves were fattened in the winter time and upon dry feeds altogether, the gains as shown in the table below were produced at an unusually small expense. This was due largely to the fact that the animals were young. The younger the animal the more cheaply can the gains be made. As a rule, the feeder can not expect to produce gains as cheaply on mature as on young cattle.

TABLE 10.—*Quantity and cost of feed required to make 100 pounds of gain.*

Number of animals.	Ration.	Pounds of feed required to make 100 pounds of gain.	Cost of feed to make 100 pounds of gain.
		Pounds.	
52	Cottonseed meal	249	$6.97
	Cottonseed hulls	806	
	Mixed cowpea hay	121	

It is seen that 249 pounds of cottonseed meal, 808 pounds of cottonseed hulls, and 121 pounds of hay were required to make 100 pounds of gain; or, when feeds are valued as on page 23, it cost $6.97 to make 100 pounds of increase in live weight.

AMOUNT REALIZED ON EACH TON OF FEED WHEN PRICES OF THE OTHER FEEDS ARE FIXED.

This test again emphasizes the facts, first, that the farmer can well afford to buy commercial feeds for his beef animals during the fattening process, and second, when he has home-raised feeds to sell greater prices can be realized on them when they are sold by means of live stock than when sold upon the general grain or hay market. Each ton of feed used was sold, by means of the calves, for the following prices:

Price realized on each ton of cottonseed meal when other prices are fixed	$46.32
Price realized on each ton of cottonseed hulls when other prices are fixed	13.24
Price realized on each ton of mixed hay when other prices are fixed	56.61

Cottonseed meal cost $26 a ton, but it was sold, by means of the calves, for $46.32 a ton. The cottonseed hulls cost $7 a ton and this sum was nearly doubled by means of the calves, the price realized being $13.24 a ton. The price realized on the hay was, of course, abnormally high, as not much hay was fed; only 4.37 tons were used throughout the whole test, but this small amount was sold, by means of the calves, for $56.61 a ton when cottonseed meal and hulls are valued at $26 and $7 a ton, respectively.

FINANCIAL STATEMENT.

At the beginning of the experiment the calves were valued at 3 cents a pound. When they were ready to be sold, March 29, 1911, they were shipped to New Orleans, where they sold for an average of $5.55 per hundredweight. All expenses were taken into consideration in the financial statement below, such as freight, feed, yardage, and commission for selling in New Orleans. These calves were not sold by farm weight, so the financial statement is based on New Orleans weights and prices:

TABLE 11.—*Financial statement.*

By sale of 52 calves, 23,212 pounds, at $5.55		$1,288.27
To 52 calves, 16,304 pounds, at 3 cents a pound	$489.12	
To 17,900 pounds of cottonseed meal, at $26 a ton	232.70	
To 58,303 pounds of cottonseed hulls, at $7 a ton	204.06	
To 8,743 pounds of mixed pea-vine hay, at $15 a ton	65.57	
To shipping expenses, commission, yardage, etc., on 52 calves	114.92	
Total expense		1,106.37
Total profit		181.90
Profit per calf		3.50

After all expenses were charged against the calves they netted a clear profit of $3.50 each. This was a satisfactory profit. It cost $2.21 to ship each calf to New Orleans and pay all the selling expenses upon their arrival; the total shipping expense amounted to 49 cents for each 100 pounds live weight.

SLAUGHTER RECORDS.

As stated before, these calves were shipped to New Orleans, where slaughter records were secured. They were driven 3 miles to the railroad at Bellamy, Ala., to be loaded on the cars:

TABLE 12.—*Slaughter data.*

Number of calves.	Live weights.			Shrinkage.		Per cent dressed.	
	Total on farm.	On farm after 3 per cent shrink.	At New Orleans.	Total.	Average per calf.	By shrunk farm weight.	By market weight.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*
45	20,475	19,861	19,935	540	12	52.8	52.7

There were 52 calves altogether, but the dressed weights of only 45 were secured. The animals lost an average of 12 pounds each during the trip to New Orleans; this was an unusually small shrinkage. They dressed out 52.7 per cent by New Orleans weights, and 52.8 per cent by farm weights, after a 3 per cent shrink.

SUMMARY.

The second experiment is summarized as follows:

TABLE 13.—*Summary statement.*

Total number of calves			52
Average weight of each calf at beginning of test (Dec. 7, 1910)		pounds	313
Average weight of each calf at end of test (Mar. 29, 1911)		do	452
Average gain of each calf		do	139
Average daily gain each calf for 112 days		do	1.24
Pounds feed required to make 100 pounds of gain	meal	do	249
	hulls	do	808
	hay	do	121
Cost to make 100 pounds of gain			$6.97
Price realized on each ton cottonseed meal, prices of other feeds being fixed			$46.32
Price realized on each ton cottonseed hulls, prices of other feeds being fixed			$13.24
Price realized on each ton hay, prices of other feeds being fixed			$56.61
Value of calves at beginning of test (Dec. 7, 1910)		hundredweight	$3.00
Selling price of calves at New Orleans, Mar. 29, 1911		do	$5.55
Total profit on each calf			$3.50

1. The calves used in this test were from 6 to 8 months old when the experiment began, December 7, 1910.

2. They were valued at $3 per hundredweight when the test began.

3. At the beginning of the test the calves averaged 313 pounds in weight; at the close (Mar. 29, 1911) they had attained an average weight of 452 pounds. They made an average daily gain of 1.24 pounds.

4. There were required 249 pounds of cottonseed meal, 808 pounds of cottonseed hulls, and 121 pounds of mixed cowpea hay to make 100 pounds of increase in live weight. The cost of 100 pounds gain was $6.97.

5. The price realized for each feed when sold through the calves, and when the prices of the other feeds were fixed, was as follows: Cottonseed meal, $46.32 per ton; cottonseed hulls, $13.24 per ton; pea-vine hay, $56.61 per ton.

6. On March 29, 1911, the calves were shipped to New Orleans and sold for $5.55 per hundredweight. Each calf netted a clear profit of $3.50.

III. WINTERING CALVES FOLLOWED BY FATTENING ON PASTURE.

The third experiment was carried on in cooperation with Messrs. Cobb and McMillan, of Sumter County, Ala. As in the previous test (Part I of this bulletin), these farmers furnished the cattle and the feed, and the Bureau of Animal Industry and the Alabama Experiment Station placed a trained man upon the farm to carry on the experimental work. One of the authors of this bulletin, Mr. W. F. Ward, was stationed on the farm and had personal supervision of the test.

PLAN AND OBJECT OF THE WORK.

The calves in this experiment were born during the spring of 1909. During the summer of 1909 they were with their mothers on a reasonably good pasture and received no particular attention except being salted regularly. When fall arrived and the pastures were exhausted they were taken from their mothers, weaned, tagged, dehorned, and the males castrated. They were then put up in an acre lot in which there was no grass, and were fed all winter on a ration of cottonseed meal, corn chop, cottonseed hulls, and mixed alfalfa hay. The object was to give them sufficient feed to produce good gains all through the winter months, but not to fatten them for the market until the pasture was available in the following spring. By the latter part of March, 1910, sweet clover (Melilotus) had appeared, so the calves were changed from the winter feed to this pasture and fed some cottonseed cake and alfalfa hay in addition. They were kept upon this pasture until June 22, 1910, when they were sold. During the latter part of the grazing season there was some Japan clover (Lespedeza) and Bermuda in the pasture. During all this time the calves were given a small daily feed of cottonseed cake along with the pasture.

The object of the work was to determine the profit, if any, in handling and feeding beef calves in accordance with the above plan.

THE CALVES.

The 34 calves used in this test were a good grade; none of them was purebred, but the majority contained from one-half to three-fourths of Aberdeen-Angus, Hereford, or Shorthorn blood. The majority of the calves were raised on the farm where the experimental work was done; some few of them, however, were purchased from neighbors just before the inauguration of the experiment. As before

CALVES FATTENING ON PASTURE. CONDITION OF ANIMALS FIVE WEEKS BEFORE END OF TEST (PART III).

stated, they had all been born during the spring of 1909, so were from 7 to 8 months old when they were first weighed, December 3, 1909. For their age they were not large, although they were larger than the average calves of the State. At the beginning of the work their average weight was 386 pounds.

FEED AND MANAGEMENT.

December 3, 1909, the calves were placed in the acre lot, in which was a good shed that afforded ample protection from cold rains and wind. On the above date the winter feeding began. They were salted at regular intervals. Good, clean, fresh water was kept in troughs all of the time. The hay racks and the feed bunks or troughs were all under shelter so that the calves could eat in a comfortable place no matter how inclement the weather became. During the winter months they were fed twice daily, once early in the morning and again an hour or so before dark.

When the grass appeared in the spring (March 22, 1910) each calf was weighed and all were turned upon the pasture to be fattened on grass. While on pasture they were fed only once a day, and this was done about sundown, or in the cool part of the afternoon, so that all would come out to the feed troughs. The feed, which consisted of cottonseed cake and alfalfa hay, was not thrown upon the ground; the cake was placed in feed troughs situated at convenient places in the pastures, and the hay was fed from hay racks. When cattle are thus fed in properly constructed hay racks and troughs practically no feed is wasted.

The pasture was not free from ticks, so the calves became slightly infested. However, they were dipped at irregular intervals, and very few ticks appeared on them. No Texas fever cases developed.

A good supply of water was afforded by a creek and an artificial pool.

THE PASTURE.

In the western part of Alabama sweet clover (Melilotus) appears earlier than any other pasture plant. In the spring of 1910 this clover pasture was ready for grazing by March 22, but it did not afford complete and satisfactory grazing at this early date. However, no hay was used to supplement the pasture until April 29, when a small allowance of freshly cut alfalfa hay was added to the pasture and cake ration. Later on in the season the sweet clover died down, when Japan clover (Lespedeza), some Bermuda, and carpet grass constituted the main grazing plants.

The pasture had been in cultivation during the season of 1909, so did not furnish ample grazing, as the grasses had not become thoroughly established. Still the calves made good and economical gains during the pasture season. The 34 animals were grazed upon a field which contained practically 100 acres.

CHARACTER AND PRICES OF FEEDS.

Cottonseed meal, cottonseed cake, cottonseed hulls, corn chop, and freshly cut alfalfa hay were all used at various times throughout the test. The purchased feeds were charged against the calves at the market prices. Estimated prices, corresponding as nearly as possible to the market prices, were placed upon the two feeds which were grown upon the farm. The following prices were placed upon the feeds:

Cottonseed meal	per ton	$26.00
Cottonseed cake (broken)	do	26.00
Cottonseed hulls	do	7.00
Corn chop	per bushel	.70
Alfalfa hay	per ton	15.00
Pasture	per head per month	.50

During the winter months a hay made up of a mixture of Johnson grass and alfalfa was fed, but that which was fed along with the pasture was practically all freshly cut alfalfa. The corn, which was grown on the farm, was used in the shape of corn chop, the shelled corn being run through a grinder which crushed the grain into a coarse meal. The cottonseed meal and the cottonseed cake were both purchased from a near-by oil mill. The cake had been broken into nut size and sacked; this had been done at the mill. All of the feeds were of good quality.

DAILY RATIONS.

As noted in the early part of this bulletin, young animals must be fed with a great deal of care and skill; they require more care and attention than steers and oxen. These calves were fed at practically the same hour each day, and received a definite amount of feed. This daily allowance of feed was limited, and it was expected that the troughs would be clean within an hour after each feeding.

TABLE 14.—*Daily feed for each calf for the whole period (Dec. 3, 1909, to June 22, 1910).*

Period.	Daily ration.	
	Winter period (Dec. 3 to Mar. 24).	Pasture period (Mar. 25 to June 22).
	Pounds.	*Pounds.*
First 28 days	2.18 cottonseed meal 1.38 corn chop 3.93 mixed alfalfa hay 7.13 cottonseed hulls	3.23 cottonseed cake.
Second 28 days	1.68 cottonseed meal 2.40 corn chop 3.99 mixed alfalfa hay 7.23 cottonseed hulls	3.85 cottonseed cake. 1.59 alfalfa hay.
Third 28 days	1.38 cottonseed meal 1.07 corn chop 3.82 mixed alfalfa hay 9.39 cottonseed hulls	5 cottonseed cake. 2.74 alfalfa hay.
Fourth 28 days	1.48 cottonseed meal .72 corn chop 3.36 mixed alfalfa hay 10.24 cottonseed hulls	5 cottonseed cake.[1] 2.74 alfalfa hay.[1]

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[1] Remainder of pasture season, 5 days.

It will be seen that the calves did not get a heavy grain ration at any time. For the first 28 days of the winter period each calf was given practically 3.5 pounds of grain each day; during the second period of 28 days the quantity was raised to 4 pounds for each calf daily. This quantity was too expensive, though, so the grain part of the ration was reduced considerably during the third period of 28 days. The object was to get these calves through the winter as cheaply as possible, and still produce reasonable and steady gains. The pasture was looked forward to as the feed for making rapid and cheap gains, so the high-priced winter feeds were used as sparingly as possible. It will be seen later, however, that the calves made satisfactory gains in the winter months.

During the winter months a definite quantity of cottonseed hulls was weighed out to the animals at each feed. It will be seen that for the first 28 days each calf ate 7.13 pounds of hulls daily, while during the last 28 days the daily allowance was raised to 10.24 pounds. Alfalfa hay was fed ad libitum; they were given all they cared to eat after receiving the regular feed of hulls and concentrates. They did not consume much alfalfa hay, however, as the average was under 4 pounds daily.

When the pasture season arrived, March 25, 1909, the calves were turned upon grass and given an average daily feed of 3.23 pounds of cottonseed cake for the first 28 days. The pasture was not good at this early date, and the calves made only 0.23 of a pound average daily gain per head during the first period. It would probably have been profitable at this time to have supplemented the pasture with some alfalfa hay, but the hay could not be secured. By April 29 a new crop of alfalfa had been cut, so that date marked the beginning of the use of the hay. After this date hay was fed each day until the calves were sold. During the last 33 days of the test each calf was given a daily feed of 5 pounds of cottonseed cake and 2.74 pounds of alfalfa hay along with the pasture.

WEIGHTS AND GAINS.

These calves were larger than those used in the test reported in Part I. When the test began the calves averaged 386 pounds in weight; when it closed, they averaged 628 pounds, or they made an average total gain of 242 pounds each from December 3, 1909, to June 22, 1910. Taken as a whole, the gains were entirely satisfactory.

TABLE 15.—*Total and daily gains.*

Period.	Number of calves.	Number of days fed.	Average initial weight of each calf.	Average final weight of each calf.	Average total gain of each calf.	Average daily gain of each calf.
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Winter period (Dec. 3, to Mar. 24)	34	112	386	512	126	1.13
Pasture period (Mar. 25 to June 22)	34	89	509	628	119	1.33

The calves were in the test 201 days. For the first 112 days they were on dry winter feed; during the final 89 days they were on pasture. Each calf made an average total gain of 126 pounds from December 3, 1909, to March 24, 1910, or an average daily gain of 1.13 pounds. This was satisfactory. On March 24, they averaged 512 pounds in weight and were from 11 to 12 months of age.

During the pasture season of 89 days (March 25 to June 22), the calves made an average total gain of 119 pounds each, or an average daily gain of 1.33 pounds. These gains were also satisfactory, but nothing unusual. When the test closed on June 22 the calves had reached an average weight of 628 pounds. They were from 14 to 15 months old at this time.

QUANTITY AND COST OF FEED REQUIRED TO MAKE 100 POUNDS GAIN.

The table below shows the average daily ration for each calf, the pounds of feed required to make 100 pounds of increase in live weight, and the cost to make the gains. In this connection it should be remembered that these were young and small animals. As a result of their being young and small their daily feed was small and their gains were made economically.

TABLE 16.—*Average daily ration and quantity and cost of feed to make 100 pounds of gain.*

Period.	Ration.	Average daily feed per calf.	Pounds feed to make 100 pounds of gain.	Cost to make 100 pounds of gain.
		Pounds.	*Pounds.*	
Winter period (Dec. 3 to Mar. 24)	Cottonseed meal	1.68	149	$8.63
	Corn chop	1.39	123	
	Cottonseed hulls	8.49	754	
	Mixed alfalfa hay	3.77	335	
Pasture period (Mar. 25 to June 22)	Cottonseed cake	4.06	305	4.84
	Alfalfa hay	1.55	116	

It cost $8.63 to make 100 pounds of gain during the winter period but the same gains were made for only $4.84 when the calves were on pasture and received a partial ration of cottonseed cake and alfalfa hay. This strikingly illustrates the importance and value of pastures. During the winter months expensive gains are almost always encountered, no matter what kind of live stock is being raised or fattened. This condition of affairs is usually due to two factors. First, the feeds which are used during the winter months are the high-priced ones, and, second, smaller gains are usually secured (especially with young and growing stock) during the cold months, and small gains are almost always expensive.

The cost of the summer gains was small compared with that of the winter gains, yet these summer gains were unusually expensive. In previous pasture-feeding work in this State[1] summer gains have been made for $2.56 to $3.24 per hundred pounds increase in live weight when cake was fed along with the pasture. The short pasture during the early part of the test probably accounts for the expensive gains; the calves made a daily gain of only 0.23 of a pound during the first 28 days of the summer feeding.

PRICES REALIZED FOR FEEDS AS A RESULT OF FEEDING TO CALVES.

It will be seen below that excellent prices were realized upon all of the feeds used during the fattening period. By means of the calves the feeds were sold for a greater price than they would have brought had they been placed upon the open grain or hay markets. The feeds brought the following prices as a result of being fed to the calves:

Cottonseed meal	per ton	$45.93
Corn chop	per bushel	1.37
Cottonseed hulls	per ton	10.99
Hay fed in winter	do	23.89
Cottonseed cake	do	35.82
Alfalfa hay during pasture season	do	21.48
Pasture rental	per head per month	1.06

The cottonseed cake cost $26 a ton, but was resold, by means of the calves, for $35.82 a ton, as above shown. If the hay had been sold on the market it would have brought approximately $15 a ton, but when it was fed to the calves and marketed by means of them each ton realized $21.48 to $23.89. When measured in terms of profits made on the calves, the pasture was rented for $1.06 a month for each calf. If the corn had been hauled to town and sold it would not have brought over 70 cents a bushel, but when it was fed to the calves each bushel realized $1.37. The cottonseed meal and hulls were sold through the calves for $45.93 and $10.99 a ton, respectively.

These results all emphasize the fact that the farmer can usually sell his farm crops by means of some kind of live stock for more than can be obtained for them when placed on the markets as raw farm products.

FINANCIAL STATEMENT.

As stated before, the majority of these calves were raised on the farm where the work was done. As they were not purchased on the open market, an estimated fall value was placed upon them. They were estimated to be worth 3½ cents a pound when the winter work began, December 3, 1909. They were fed through the winter, all feeds being charged against them at the regular market prices, so by the time spring arrived they had cost considerably more than the above fall price. The following statement shows the complete cost of the calves up to March 25, 1910:

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[1] See Bureau of Animal Industry Bulletin 131, or Alabama Station Bulletin 151.

TABLE 17.—*Total cost of the calves on March 25, 1910.*

To 34 calves, 13,118 pounds at 3½ cents (fall value)	$459.13
To 6,414 pounds cottonseed meal at $26 a ton	83.38
To 5,303 pounds of corn chop at 70 cents a bushel	66.21
To 32,356 pounds of cottonseed hulls at $7 a ton	113.25
To 14,380 pounds of mixed alfalfa hay at $15 a ton	107.85
Total cost of calves March 25, 1910	829.82

On March 25, 1910, the 34 calves weighed 17,313 pounds, and their total cost had reached $4.79+per hundredweight, consequently they were valued at this sum for the pasture work. It cost $10.90 to feed each calf from December 3, 1909, to March 24, 1910.

TABLE 18.—*Results of fattening the calves on pasture.*

By sale of 34 calves, 20,702 pounds, at 5½ cents a pound		$1,138.61
To 34 calves, 17,313 pounds, at $4.79 + per cwt	$829.82	
To 12,291 pounds cottonseed cake at $26 a ton	159.78	
To 4,691 pounds alfalfa hay at $15 a ton	35.18	
To total pasture rent, 89 days (Mar. 25 to June 22), at 50 cents per head per month	50.43	
Total expenses		1,075.21
Total profit		63.40
Profit per calf		1.86

These calves were sold June 22, 1910, for 5½ cents a pound on the farm, after a 3 per cent shrink. They were shipped to the Meridian (Miss.) market for slaughter.

The above shows that a profit of $1.86 was made on each calf after all expenses were taken into account. The financial statement means that the calves were put into the test at 3½ cents a pound in the fall of 1909; that the alfalfa hay which was grown on the farm was sold for $15 a ton; that the corn, which was also produced upon the farm, was disposed of for 70 cents a bushel; and, finally, that an additional profit of $1.86 was made on each calf. This was satisfactory, especially when it is recalled that a large amount of manure was produced while the calves were being fed.

SLAUGHTER RECORDS.

The calves were shipped to Meridian, Miss., for slaughter. They were driven to Scooba, Miss., a distance of 11 miles, to be loaded on the cars. Through a misunderstanding the live weights were not secured at Meridian, but the individual weights of the dressed carcasses were all secured.

TABLE 19.—*Slaughter data.*

Number of calves.	Live weights.		Dressed weight.	Per cent dressed by shrunk farm weight.
	Total on farm.	On farm after 3 per cent shrink.		
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
34	21,342	20,702	11,258	54.4

It will be seen that the calves dressed out, by farm weights, after allowing 3 per cent for shrinkage, 54.4 per cent, which is nearly 2 per cent higher than the best showing of the winter-fed calves in Parts I and II. The carcasses were good ones and made an excellent appearance when hung up in the cooler.

SUMMARY.

TABLE 20.—*Summary Statement.*

Cost of calves fall of 1909		$3.50
Average weight of calves Dec. 3, 1909	pounds..	386
Average daily ration from Dec. 3, 1909, to Mar. 24, 1910:		
Cottonseed meal	do....	1.68
Corn chop	do....	1.39
Cottonseed hulls	do....	8.49
Mixed alfalfa hay	do....	3.77
Average weight of calves Mar. 24, 1911	do....	512
Average daily gain during the winter months	do....	1.13
Cost to make 100 pounds increase in live weight during the winter months		$8.63
Cost to feed each calf through the winter months		$10.90
Total cost of calves when put on pasture Mar. 24, 1910	per cwt..	$4.79+
Cost to make 100 pounds increase in live weight on pasture		$4.84
Each ton of cottonseed cake was sold, prices of other feeds being fixed, by means of calves, for		$35.82
Each ton of alfalfa hay was sold, prices of other feeds being fixed, by means of calves, for		$21.48
Selling price of calves on farm, after 3 per cent shrink	per cwt..	$5.50
Profit on each calf		$1.86

1. The calves used in this work were of a good grade. They were from 7 to 8 months old when the test began.

2. They were fed through the winter of 1909–10 on cottonseed meal, corn chop, cottonseed hulls, and mixed alfalfa hay. In the spring of 1910 the calves were put in a pasture and finished for the market on pasture, cottonseed cake, and alfalfa hay.

3. During the winter season (Dec. 3, 1909 to Mar. 24, 1910) the calves made an average total gain of 126 pounds, or an average daily gain of 1.13 pounds.

4. During the pasture season (Mar. 25, 1910 to June 22, 1910) the calves made an average total gain of 119 pounds, or an average daily gain of 1.33 pounds.

5. During the winter season 149 pounds of cottonseed meal, 123 pounds of corn chop, 754 pounds of hulls, and 335 pounds of hay, at a total cost of $8.63, were required to make 100 pounds of increase in live weight.

6. During the pasture season 305 pounds of cottonseed cake and 116 pounds of alfalfa hay, at a total cost of $4.84, were required to make 100 pounds of increase in live weight.

7. Each ton of cottonseed cake was sold, by means of the calves, for $35.82 when the other feeds were valued as indicated in this bulletin.

8. Each ton of alfalfa hay was sold, by means of the calves, for $21.48 when the other feeds were valued as indicated in this bulletin.

9. Each ton of cottonseed meal was sold, by means of the calves, for $45.93 when the other feeds were valued as indicated in this bulletin.

10. Each ton of cottonseed hulls was sold, by means of the calves, for $10.99 when the other feeds were valued as indicated in this bulletin.

11. Each bushel of corn chop was sold, by means of the calves, for $1.37 when the other feeds were valued as indicated in this bulletin.

IV. GENERAL STATEMENT.

While the calves in Parts I, II, and III of this bulletin were fattened in different ways and by different methods, all were raised and handled in the same manner up to the time of being placed in the dry lots. All were born during the spring months and ran with their mothers on a reasonably good pasture during their first summer; they ate nothing but mother's milk and pasture grasses during this time. When the pasture season closed, which was practically December 1 each year, the calves were weaned, dehorned, the males castrated, and all placed in feed lots to be fattened. At this time the different methods as previously outlined were introduced. In Part I the calves were divided into three lots and fattened upon cottonseed meal, corn-and-cob meal, cottonseed hulls, and alfalfa hay, for the early spring market; in Part II the calves were all fed in the same lot and finished for the early spring market on cottonseed meal, cottonseed hulls, and pea-vine hay; in Part III they were carried through their first winter on a ration slightly below a full feed and fattened the following summer on pasture supplemented by cottonseed cake and alfalfa hay.

As a matter of fact, the winter feeding should have been inaugurated before December 1, as the calves lost some of their calf fat, due to short pastures and decreased milk supply, before the feeding periods began. In farm practice it would be wise either to begin the winter feeding by November 1 or to have an oat or rye pasture for the young animals to graze upon after the permanent pastures are killed by frost.

To feed calves as these were fed it is best to have them born as early as possible in the spring. This gives them an opportunity to attain a reasonable size and age by the time they are ready for sale the following spring or early summer. The southern markets prefer larger carcasses than the ones obtained from these calves. In some sections of the country, where the cows must be housed during the winter months, it is more desirable to have the calves come in the fall of the year, as the farmer has more time to care for the small animals during the winter than during the summer months, and the calves would be weaned in the spring, a season when their growth is least retarded. In the South, however, where range conditions still obtain, to have the calves come in the fall would involve the risk of losing both the mothers and the offspring.

The calves in Part I were sold March 17, those in Part II March 29, while those in Part III were fattened on pasture during the latter part of the feeding period and not disposed of until June 22. The calves in Parts I and II were practically 1 year old when sold, while those in Part III were from 14 to 16 months of age at the time of slaughter. As stated in the introduction, there are some advantages in selling calves at an early age. On the other hand, the farmer experiences difficulties in feeding young animals which are not encountered in feeding old and mature animals. In the first place, it would seldom, or never, pay to finish a poor grade of young calves for the market, as our markets sharply discriminate against young animals which carry a predominance of Jersey or scrub blood. In the second place, the farmer who feeds young animals of any kind must be a careful and watchful feeder. An old animal may be fed and handled carelessly and satisfactory results still be obtained, but not so with the young animal. A single instance of overfeeding may so derange the intestinal tract of the young animal that further development is impossible.

CONCLUSIONS.

The tests in this bulletin indicate that excellent profits may be made on calves when they are fed properly, handled carefully, and sold in a businesslike way. In Part I a clear profit of $1.84, $2.25, and $1.48 was realized on each calf in their respective lots; in Part II, where nothing was fed except cottonseed meal, cottonseed hulls, and pea-vine hay, a profit of $3.50 was realized on each animal; and in Part III, where the animals were fed a light ration of grain and hay throughout the winter months and finally finished on pasture, $1.86 profit was realized on each calf.

The reader should understand that these different experiments are not directly comparable, but they do, in a general way, teach us some lessons. The difference in profits between the calves in Parts I and II was due largely to the selling price; those in Part II simply sold to greater advantage. This difference in profits in favor of the calves in Part II was not due to the fact that they made gains more economically than those in Part I. On the contrary, the calves in Part I made 100 pounds of gain for $6.22, $6.19, and $6.83 in the respective lots, while the same gain cost $6.97 in Part II. While the calves in Part II were a cheaper grade than those in Part I (being valued at 3 cents a pound when the test began, while those in Part I were valued at 3½ cents a pound), still they sold for practically the same price when placed on the market; there was a difference of one-half a cent a pound in favor of the calves in Part II. The calves in Part I were sold on the Cincinnati market, while those in Part II were shipped to New Orleans. At the present time, and in fact for some years past, both cattle and hogs have been selling for better prices on the southern than on the northern markets.

While the calves in Part III sold for a better price than those in the other tests, still they were not as profitable as some of the others. The selling price alone does not determine the final profit; other factors must be considered. It is seen that the winter gains in this test were expensive, costing $8.63 to make 100 pounds. While the cost of the subsequent pasture gains was small as compared to the winter gains, they were not sufficiently cheap to overcome the preceding high-priced gains and thereby make a profit that was entirely satisfactory. Notwithstanding the fact that a profit was made on these calves, the authors are of the opinion that a greater profit would have been made if they had been fed more liberally during the winter months and sold in March or April instead of in June. The expensive winter gains were due to the fact that the animals were held below a full ration, which goes to show that the nearer the feeder approaches a mere maintenance ration the more expensive will be the gains. If the calves had been given a full feed, or almost a full feed, during the winter months, their gains would have been considerably greater than they were, and at the same time more economical. The test, however, does illustrate the value of pastures for making cheap gains.

SUMMARY OF CONCLUSIONS.

This experimental work is being continued, but at the present time the following general conclusions, based on the work already done, can be drawn:

1. A farmer may expect to obtain a reasonable profit on beef calves when he raises and fattens them on his farm and sells them when they are 12 to 14 months old. That is, the farmer who feeds his corn and hay to these young animals can realize more on these raw farm products, when sold through the calves, than when sold as corn or hay. At the same time a large amount of manure is made on the farm to enrich the soil.

2. In the South, at least in Alabama at the present time, the calves should be born during the early spring months.

3. The southern feeder has the choice of many different feeds suitable for fattening calves. With reference to the feeds reported in this bulletin the following conclusions are warranted:

(*a*) When fattening calves it pays to feed a ration made up of one-third corn-and-cob meal and two-thirds cottonseed meal, when corn is valued at 70 cents a bushel and meal at $26 a ton.

(*b*) It is not profitable for two-thirds of the concentrated part of the ration to be composed of corn-and-cob meal when the feeds are valued as above.

(*c*) Young calves can be finished for the market at a profit on cottonseed meal, cottonseed hulls, and pea-vine hay, but it is more profitable to introduce corn-and-cob meal to take the place of part of the cottonseed meal.

4. When shall the calves be sold? The tests seem to indicate that it is more profitable to feed a heavy ration and sell the calves at the end of the winter months when prices are normally high, than to hold them until the early summer months. Light winter feeding produces expensive gains. Although the subsequent pasture gains are made much more cheaply than the winter gains, they are not made economically enough to overcome or counteract the preceding high-priced slowly-made winter gains, together with the normal depreciation in the value of cattle from March or April to June or July.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 148.
A. D. MELVIN, CHIEF OF BUREAU.

THE MANUFACTURE OF BUTTER FOR STORAGE.

BY

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1912.

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LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., March 27, 1912.

SIR: I have the honor to transmit herewith, and to recommend for publication in the bulletin series of this bureau, a manuscript entitled "The Normal Composition of American Creamery Butter," by Messrs. S. C. Thompson, R. H. Shaw, and R. P. Norton, of the Dairy Division.

The production of creamery butter has reached vast commercial proportions, and different standards are in force in the various States for the regulation of its quality and chemical composition. Much analytical work has already been published on the composition of butter, but most of it is lacking in certain essential details, with the result that little definite information regarding the normal composition of American creamery butter as now manufactured is available. A comprehensive study of the subject was undertaken by the Dairy Division, and this paper records complete analytical details of some 700 samples of creamery butter derived from 14 States. This work was done under the direction of Mr. B. H. Rawl, chief of the Dairy Division.

Respectfully,

A. D. MELVIN,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE NORMAL COMPOSITION OF AMERICAN CREAMERY BUTTER.

INTRODUCTION.

During recent years the composition of butter, from a quantitative point of view, has been a subject of considerable interest. Reports of thousands of analyses for water and other constituents have appeared in various publications from time to time, but data showing the composition of normal American creamery butter and the conditions under which such butter is made are not plentiful. Hence it has been deemed advisable to make a comprehensive study of the subject.

The purpose of this bulletin is to present in a variety of ways the results of the chemical analyses of American creamery butter collected, during a period of one year, from a large number of representative creameries throughout the principal dairy districts of the United States, and to include a record of the conditions under which the butter was made.

The authors acknowledge the assistance and cooperation of the dairy and food departments of the various States mentioned in this bulletin, all of which rendered valuable aid in securing samples of butter.

PREVIOUS INVESTIGATIONS.

There is no lack of published data on the composition of American creamery butter, but such data represent, very largely, analyses made on miscellaneous samples, the sources of which are more or less obscure and the churning conditions unknown. Nothing would be gained by reviewing the mass of analyses, the great majority of which concern the moisture content alone, or were made in connection with investigations on other subjects. A brief review of some of the principal investigations follow:

The most recent and perhaps the most extended work on the composition of American creamery butter was made by Lee and Barnhart, of the Illinois Experiment Station, in 1909, and published as

Bulletin 139 of that station. They analyzed butter made in several States and purchased on the open market at Chicago, Elgin, and Aurora. Their work extended over a year. The main points in their summary are here quoted:

> Average composition of 574 samples of market butter collected for a period of one year, beginning March, 1907, was: Water, 13.54; fat, 83.20; salt, 2.25; and casein and ash, 0.90 per cent.
>
> There was no difference in the composition of butter caused by the season of the year, the State where it was made, of the dealer by whom it was handled.
>
> Average composition of 60 samples of "convention butter" was: Water, 12.54; fat, 84.65; salt, 1.77; and casein and ash, 1.02 per cent.

The Dairy Division published in 1902, as circular 39 of the Bureau of Animal Industry, United States Department of Agriculture, the average water content of 802 samples of creamery butter, from 400 different creameries located in 18 States. The average water content was 11.78 per cent.

C. W. Fryhofer, of the Dairy Division, analyzed butter purchased on the New York market during 1907. This work has hitherto been unpublished, and the results are as indicated in the following table:

Analysis of butter purchased on the New York market in 1907.

Contents.	Samples tested.	Average per cent.
Butterfat	170	82.35
Water	828	13.72
Salt	142	2.15
Curd	169	.88

The Massachusetts Experiment Station Report for 1892 gives the following average analysis of 25 samples of butter: Fat, 83.95; salt, 4.74; curd, 0.66 per cent (water not given).

Iowa Experiment Station Bulletin 80 gives the following average analysis of 224 samples of butter (State educational contest): Fat, 83.91; water, 12.87; salt and ash, 1.98; curd, 1.23 per cent.

THE EXPERIMENTAL WORK.

AREA COVERED.

The area covered in this investigation embraces 14 States, namely, California, Iowa, Kansas, Maine, Michigan, Minnesota, Montana, New York, North Dakota, Oklahoma, Pennsylvania, South Dakota, Texas, and Wisconsin. The samples were taken during a period of one year from 488 creameries, and the total number which reached the laboratory in good condition for analysis was 695.

METHOD OF SAMPLING.

The samples in all cases were collected by Federal and State officials who appreciated the necessity of proper sampling. The following instructions were given each official:

> The samples may be taken with a trier or by stripping a tub and cutting a V-shaped wedge from top to bottom of tub. The sample should be large enough to about fill the can. A sharp knife is satisfactory for cutting out the butter, which may be put into the can piece by piece until the can is about full. The cover should be pressed on tight, the can placed in the mailing tube, and mailed to the Dairy Division.
>
> Be sure to note the number on sticker pasted on the can and mark the same number on the detailed report of manufacture. These should be filled out for one day as fully as possible and returned to us. This work may have an important value on the future standard for butterfat in butter, and we request caution in every particular. If the sample of butter is not taken from the tub it may be taken from the churn after the butter is worked and ready to pack. The surface of the butter should be stroked with a ladle to remove free moisture appearing on the surface and then take about 10 samples from different parts of the churn, which put directly into the can. If the sample is to be taken from the print, cut off from one end enough to fill can.

The samples were placed in half-pound friction-top cans, which were inclosed in mailing tubes and sent to Washington. With the exception of a few, which were discarded, the samples were received in good condition.

A number of samples were taken from the creameries making and packing butter for the United States Navy. These are considered separately, since the butter was made under contract specifying the quantity of salt and water permitted.

METHOD OF ANALYSIS.

The samples were mixed by placing them, while still in the cans, either in warm water or on the steam bath and stirring until the mass was of the consistency of thick cream. In this condition—that is, when the butter is not solid and yet not liquid enough to pour—it can be thoroughly mixed. The charges, in duplicate, were taken after mixing in this manner.

The fat, water, and curd[1] were determined according to the official method as described in Bulletin 107 (revised) of the Bureau of Chemistry, United States Department of Agriculture.

The salt was determined by the hitherto unpublished method devised by C. E. Gray, formerly chemist in the Dairy Division, the details of which are as follows:

> Volumetric flasks of 250 c. c. capacity are used, which are provided with a second mark representing the volume of 250 c. c. plus the volume occupied by the fat in 5 grams of average butter at about 80° C. Five grams of the butter to be tested are weighed into a small beaker and washed with hot water into the volumetric flask. The flask and contents are then vigorously shaken and hot water added until the upper

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[1] The term "curd" as used in this bulletin includes the ash and lactose.

layer is considerably above the second mark. The flask is then allowed to stand until the fat has risen into the neck and the upper layer settled to the upper mark, caused, of course, by contraction on the cooling of the liquid. At this point a 50 c. c. pipette is thrust into the flask and aliquots representing 1 gram quickly removed. The fat is prevented from entering the pipette by holding a finger over its mouth until the point is well below the fat layer. After cooling, the aliquots are titrated in the usual manner with a standard silver nitrate solution, using potassium chromate as indicator.

This method has been found to compare very favorably with the official method in accuracy and has the advantage of being much more rapid.

RESULTS OF THE ANALYSES.

A general table, which contains the original data of all the samples having practically complete churn records, is shown as Table I of the Appendix at the end of this paper. This table gives the samples by number, with the chemical composition and churning record of each. The following 30 tables have been constructed from the original data to facilitate study and show some of the comparisons that may be made.

Tables 1 to 12, inclusive, show averages of all samples in the aggregate. Tables 13 to 24, inclusive, have been compiled to show the average composition of butter from those States where the bulk of the samples originated. Tables 25 to 28, inclusive, give the chemical composition and churning record of those samples showing extremes in the various constituents. Tables 29 and 30 record the analysis of 34 samples of Navy butter.

GENERAL AVERAGES.

The first series of tables, Nos. 1 to 12, show the average composition of all the samples; the average composition by classes, seasons, and size of granules; the temperature of churning and of wash water by seasons; the test of buttermilk by seasons; the relation between the fat and moisture contents; and various phases of the churning conditions.

TABLE 1.—*Average composition of all samples used in the investigation.*

Number of samples.[1]	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
695	82.41	13.90	2.51	1.18

[1] This includes all samples which reached the laboratory in good condition. The churn records were, however, not complete in all cases. In the tables which follow some of the results were omitted for this reason.

The samples having complete churn records were divided into three classes: (1) Those having 84 per cent of fat and over, (2) those having less than 81 per cent, and (3) those having 81 to 84 per cent of fat. The average composition of the three classes is given below:

TABLE 2.—*Average composition of the butter by classes.*

Class.	Number of samples.	Fat.	Water.	Salt.	Curd.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	124	84.78	12.45	1.78	0.98
2	130	79.77	15.32	3.52	1.37
3	370	82.55	13.85	2.41	1.18
Variation		5.01	2.87	1.74	.39

TABLE 3.—*Average composition of the butter according to seasons in which samples were taken.*

Season.	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
January, February, March	82.46	13.94	2.49	1.10
April, May, June	82.93	13.67	2.42	.96
July, August, September	82.12	14.04	2.58	1.25
October, November, December	82.25	13.81	2.55	1.38
Variation	.81	.34	.16	.42

TABLE 4.—*Average composition of the butter according to size of granules when churning was completed.*

Size of granules.	Number of samples.	Fat.	Water.	Salt.	Curd.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Small	224	82.64	13.66	2.48	1.22
Medium	292	82.45	13.93	2.46	1.16
Large	102	81.87	14.20	2.80	1.13
Variation		.77	.54	.34	.09

TABLE 5.—*Average and range of temperature of churning according to seasons in which samples were taken.*

Season.	Average.	Highest.	Lowest.
	°F.	*°F.*	*°F.*
January, February, March	57	60	50
April, May, June	56	64	49
July, August, September	56	66	48
October, November, December	57	66	52

TABLE 6.—*Test of buttermilk according to seasons in which samples were taken.*

Season.	Average.	Highest.	Lowest.
	Per cent.	*Per cent.*	*Per cent.*
January, February, March	0.10	1.90	0.03
April, May, June	.19	1.90	.01
July, August, September	.20	1.30	.01
October, November, December	.13	.61	.02
Average of all samples	.17		

TABLE 7.—*Temperature of wash water according to seasons in which samples were taken.*

Season.	Average.	Highest.	Lowest.
	°F.	°F.	°F.
January, February, March	59	68	50
April, May, June	56	68	46
July, August, September	56	72	42
October, November, December	58	75	40

TABLE 8.—*Relation between moisture and fat content, the variations in the fat content of samples having fixed moisture content.*

Number of samples.	Per cent of samples.	Moisture.	Fat.		
			High.	Low.	Average.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
8	1.2	10 to 10.99	87.39	84.06	85.86
30	4.8	11 to 11.99	86.60	82.32	85.10
92	14.7	12 to 12.99	86.36	81.47	84.04
221	35.4	13 to 13.99	84.86	78.98	82.91
168	26.9	14 to 14.99	83.97	78.72	81.13
74	11.8	15 to 15.99	83.49	77.77	80.50
31	4.9	16 and over	81.17	73.49	78.70

TABLE 9.—*Relation between butterfat and moisture content, the variations in the moisture content of samples having fixed fat content.*

Number of samples.	Per cent of samples.	Butterfat.	Water.		
			High.	Low.	Average.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
30	4.8	Below 79	20.65	13.92	16.33
27	4.3	79 to 79.99	17.56	13.64	15.37
73	11.6	80 to 80.99	16.78	13.12	14.89
110	17.6	81 to 81.99	16.39	12.45	14.38
128	20.5	82 to 82.99	15.20	12.30	13.90
132	21.1	83 to 83.99	15.06	12.05	13.37
88	14.1	84 to 84.99	13.80	10.93	12.79
24	3.8	85 to 85.99	12.91	10.66	11.90
12	1.9	86 and above	12.02	10.13	11.13

TABLE 10.—*Churning conditions of all samples containing 84 per cent fat or more.*

Average fat content of cream churned	per cent	28.04
Average acidity of cream churned, per cent		.51
Churning temperatures:		
Highest	°F.	63
Lowest	°F.	48
Average	°F.	57.1
Length of time churned:		
Highest	minutes	120
Lowest	do	10
Average	do	46.1
Size of granules:		
Small	samples	60
Medium	do	50
Large	do	13
Not given	do	1
		124

Temperature of wash water:		
Highest	°F.	68
Lowest	°F.	43
Average	°F.	57
Revolutions in wash water:		
Highest		50
Lowest		2
Average		11.5
Revolutions in wash water (rollers in gear), 11 samples:		
Highest		25
Lowest		2
Number of revolutions worked:		
Highest		120
Lowest		9
Average		20.8

TABLE 11.—*Churning conditions of all samples containing less than 81 per cent fat.*

Average fat content of cream churned	per cent	27.8
Average acidity of cream churned, per cent		.503
Churning temperatures:		
Highest	°F	84
Lowest	°F	48
Average	°F	56.6
Length of time churned:		
Highest	minutes	330
Lowest	do	20
Average	do	53.6
Size of granules:		
Small	samples	41
Medium	do	56
Large	do	30
Not given	do	3
		130
Temperature of wash water:		
Highest	°F	68
Lowest	°F	48
Average	°F	57
Revolutions in wash water:		
Highest		82
Lowest		2
Average		19.4
Revolutions in wash water (rollers in gear), 32 samples:		
Highest		15
Lowest		2
Number of revolutions worked:		
Highest		105
Lowest		3
Average		21.1

(30 samples showed 16 per cent or more of water.)

TABLE 12.—*Churning averages of samples having 81 to 84 per cent of fat.*

Fat test of cream churned, per cent	28.01
Acidity of cream churned, per cent	.535
Time churned, minutes	45.9
Temperature at which churned, °F	56.8
Granules of butter:	
Small	130
Medium	176
Granules of butter—Continued.	
Large	62
Not given	2
	370
Temperature of wash water...°F	57.3
Revolutions in wash water	14.2
Revolutions in wash water (rollers in gear, 59 samples)	10.8
Number of revolutions worked	19.94

AVERAGES BY STATES.

Tables 13 to 24, next following, show the average composition of creamery butter secured in this investigation in a number of selected States, namely, Minnesota, Wisconsin, Iowa, California, Pennsylvania, North Dakota, Texas, and Michigan.

MINNESOTA.

TABLE 13.—*Results of analyses of 223 samples from the State.*

Percentage.	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Average	82.81	13.60	2.34	1.24
Highest	87.39	17.33	5.62	3.32
Lowest	77.53	10.13	.68	.12
Variations	9.86	7.20	4.94	3.20

NOTE.—The "highest" and "lowest" in the above table and similar tables are the highest and lowest in all the samples; that is, the highest fat percentage and the highest water percentage, for example, would not necessarily occur in the same sample.

TABLE 14.—*Number of samples having fixed percentages of each constituent, graduated from lowest to highest.*

Number of samples.	Fat.	Number of samples.	Water.	Number of samples.	Salt.	Number of samples.	Curd.
	Per cent.		*Per cent.*		*Per cent.*		*Per cent.*
1	77	2	10	8	Below 1	1	0.1
6	78	11	11	80	1	4	.2
3	79	46	12	91	2	7	.4
19	80	91	13	33	3	20	.6
37	81	54	14	9	4	31	.8
43	82	11	15	2	5	116	1.0
59	83	7	16			25	1.5
39	84	1	17			12	2.0
11	85					3	2.5
4	86					4	[1] 3.0
1	87						
223	....	223	....	223	....	223	....

[1] Or more.

NOTE.—In the above table and similar tables that follow the per cent given includes all fractions up to the next per cent given. Thus, 77 per cent includes all fractions up to 77.99 per cent.

WISCONSIN.

TABLE 15.—*Results of analyses of 117 samples from the State.*

Percentage.	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Average	82.48	13.77	2.61	1.14
Highest	86.75	18.23	5.46	2.13
Lowest	75.68	10.52	.95	.23
Variations	11.07	7.71	4.51	1.89

TABLE 16.—*Number of samples having fixed percentages of each constituent, graduated from lowest to highest.*

Number of samples.	Fat.	Number of samples.	Water.	Number of samples.	Salt.	Number of samples.	Curd.
	Per cent.		*Per cent.*		*Per cent.*		*Per cent.*
1	75	3	10	2	Below 1	1	0.2
2	77	5	11	34	1	3	.4
2	78	18	12	43	2	11	.6
3	79	47	13	23	3	30	.8
16	80	26	14	10	4	53	1.0
20	81	15	15	5	5	18	1.5
26	82	2	16			1	2.0
23	83	1	18				
16	84						
5	85						
3	86						
117	....	117	....	117	....	117	....

IOWA.

TABLE 17.—*Results of analyses of 131 samples from the State.*

Percentage.	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Average	82.11	14.24	2.51	1.12
Highest	86.08	18.54	5.96	3.25
Lowest	75.21	10.72	.94	.20
Variations	10.87	7.82	5.02	3.05

TABLE 18.—*Number of samples having fixed percentages of each constituent, graduated from lowest to highest.*

Number of samples.	Fat.	Number of samples.	Water.	Number of samples.	Salt.	Number of samples.	Curd.
	Per cent.		*Per cent.*		*Per cent.*		*Per cent.*
1	75	1	10	2	Below 1	5	0.20
6	78	4	11	41	1	6	.40
7	79	14	12	50	2	18	.60
19	80	33	13	28	3	22	.80
21	81	49	14	8	4	56	1.00
36	82	21	15	2	5	19	1.50
20	83	6	16			4	2.00
16	84	2	17			1	3.25
4	85	1	18				
1	86						
131	....	131	....	131	....	131	....

CALIFORNIA.

TABLE 19.—*Results of analyses of 95 samples from the State.*

Percentage.	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Average	82.12	14.19	2.64	1.05
Highest	86.91	20.65	5.17	3.41
Lowest	73.49	10.66	.94	.33
Variations	13.42	9.99	4.23	3.08

TABLE 20.—*Number of samples having fixed percentages of each constituent, graduated from lowest to highest.*

Number of samples.	Fat.	Number of samples.	Water.	Number of samples.	Salt.	Number of samples.	Curd.
	Per cent.		*Per cent.*		*Per cent.*		*Per cent.*
1	73	1	10	2	Below 1	1	0.2
3	78	4	11	17	1	12	.4
11	79	6	12	50	2	17	.6
9	80	31	13	16	3	24	.8
22	81	28	14	7	4	30	1.0
17	82	20	15	3	5	4	1.5
19	83	3	16			3	2.0
8	84	1	18			3	2.5
3	85	1	20			1	3.0
2	86						
95	....	95	....	95	....	95	....

PENNSYLVANIA.

TABLE 21.—*Results of analyses of 37 samples from the State.*

Percentage.	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Average	82.81	13.53	2.63	1.03
Highest	85.64	16.88	5.21	1.72
Lowest	77.92	11.72	1.35	.52
Variation	7.72	5.16	3.86	1.20

NORTH DAKOTA.

TABLE 22.—*Results of analyses of 17 samples from the State.*

Percentage.	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Average	82.40	13.63	2.81	1.15
Highest	84.83	15.73	4.29	2.70
Lowest	80.26	10.95	1.41	.48
Variation	4.57	4.78	2.88	2.22

TEXAS.

TABLE 23.—*Results of analyses of 15 samples from the State.*

Percentage.	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Average	82.76	13.98	2.15	1.11
Highest	85.58	20.23	3.83	2.33
Lowest	79.95	11.04	1.03	.52
Variation	9.63	9.19	2.80	1.81

MICHIGAN.

TABLE 24.—*Results of analyses of 10 samples from the State.*

Percentage.	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Average	80.99	14.44	3.31	1.26
Highest	83.51	16.75	5.98	2.05
Lowest	75.93	13.09	1.46	.50
Variation	7.58	3.66	4.52	1.55

The results in Tables 14, 16, and 18, which concern the States of Minnesota, Wisconsin, and Iowa, are shown graphically in comparative form in figures 1 to 4. There is this difference, however, that whereas the tables give only the number of samples for each given per-

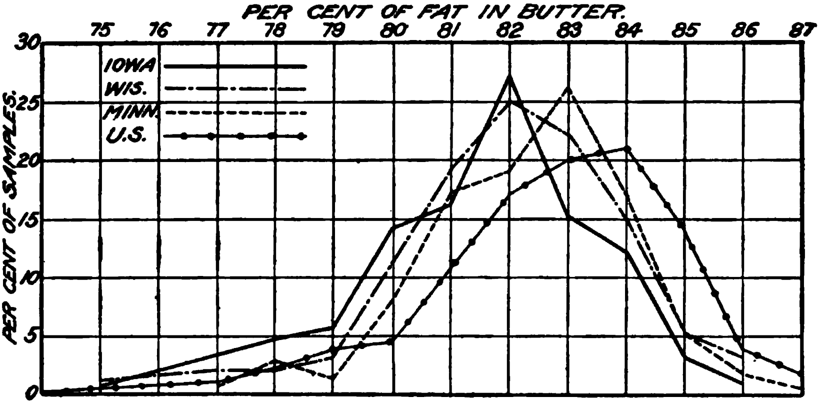

FIG. 1.—Diagram showing the fat content of the samples from Iowa, Wisconsin, and Minnesota, and of all samples in the investigation.

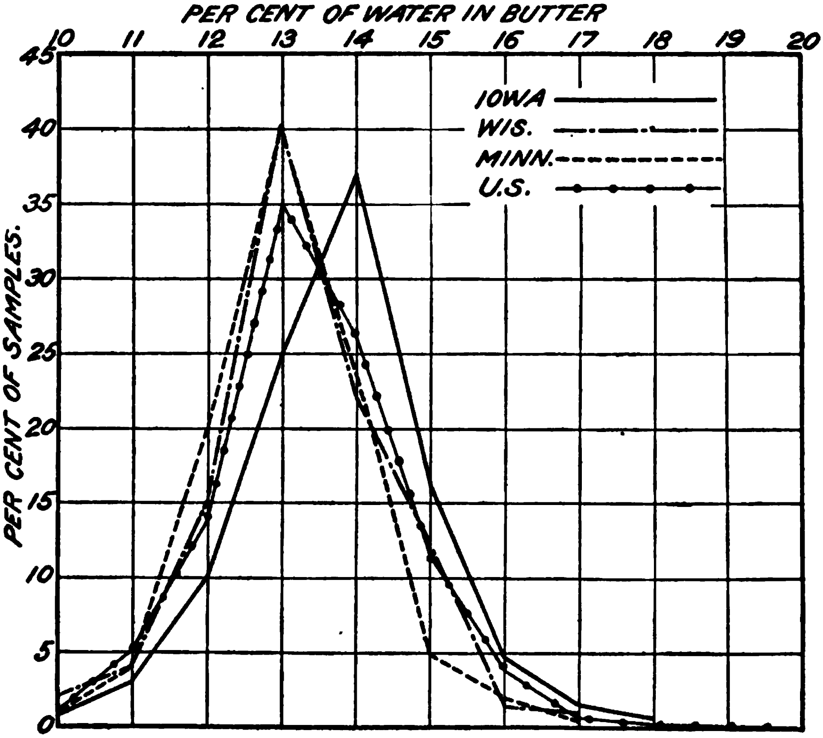

FIG. 2.—Diagram showing the moisture content of the samples from Iowa, Wisconsin, and Minnesota, and of all samples in the investigation.

centage of the various constituents of the butter, the diagrams show percentages of both samples and constituents. In addition there is added, for further comparison, a curve representing the percentages of all the samples in this investigation.

DETAILS OF SOME EXTREME SAMPLES.

In the succeeding four tables, Nos. 25 to 28, are found details of the samples, which gave, respectively, the highest fat and lowest water record, the highest water and lowest fat record, the lowest curd record, and the highest curd record.

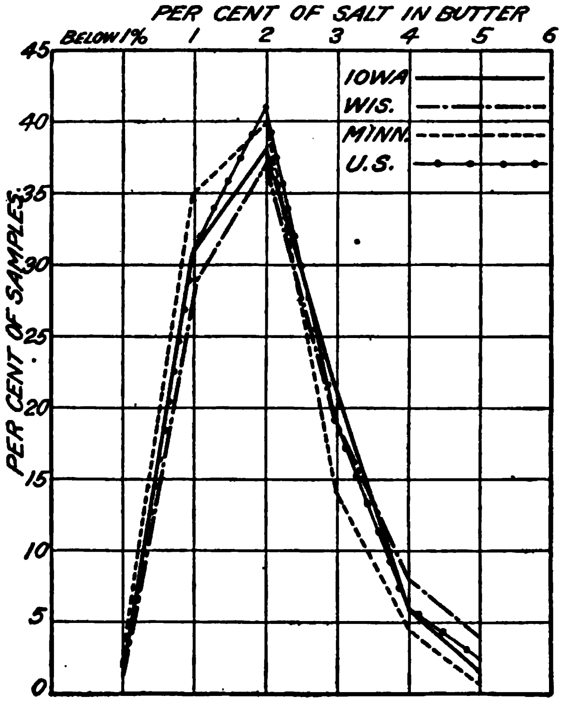

FIG. 3.—Diagram showing the salt content of the samples from Iowa, Wisconsin, and Minnesota, and of all the samples in the investigation.

TABLE 25.—*Composition and churning record of sample No. 503, which has the highest fat and lowest water content found in the investigation.*

Analysis: Butterfat 87.39, water 10.13, salt 1.76, curd 0.72; total, 100 per cent.

CHURNING RECORD.

Butter made............pounds..	410	Temperature of buttermilk...°F..	58
Ripening temperature......°F..	62	Amount of wash water......gals..	100
When cooled................	5.30 p. m.	Revolutions in wash water........	5
Temperature when ready to churn, °F.........................	57	Rollers in or out of gear...........	Out.
Length of time churning....min..	45	Number of revolutions worked....	22
Size of granules..........	Medium fine.	Kind of churn used...........	Victor F.

Churn cover closed tight while working the butter.

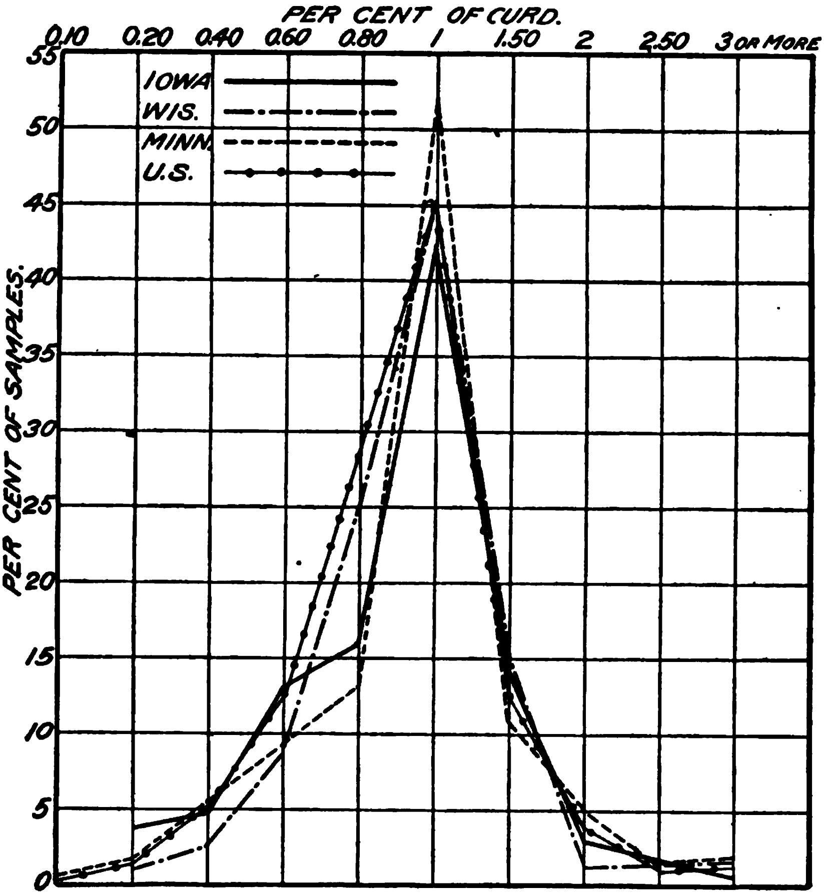

FIG. 4.—Diagram showing the percentage of curd in the samples from Iowa, Wisconsin, and Minnesota, and in all the samples in the investigation.

TABLE 26.—*Composition and churning record of sample No. 784, which has the highest water and lowest fat content found in the investigation.*

Analysis: Butterfat 73.49, water 20.65, salt 5.14, curd 0.72; total 100 per cent.

CHURNING RECORD.

Pounds of cream	1,800
Test of cream..........per cent..	30
Pounds of butter made	600
Pasteurizing temperature..°F..	180–185
Ripening temperature........°F..	48
When cooled	All night.
Temperature when ready to churn, °F	50
Kind of churn used	S.
Length of time churning....min..	60
Size of granules	Wheat.
Test of buttermilk.....per cent..	0.54
Temperature of wash water...°F..	64
Amount of wash water: 1st, as much as cream; 2d, one-third as much.	
Revolutions in wash water	4
Rollers in or out of gear	In.
Length of time worked......min..	6

Churn cover closed tight while working the butter.

TABLE 27.—*Composition and churning record of sample No. 417, which has the lowest curd content found in the investigation.*

Analysis: Butterfat 84.62, water 13.60, salt 1.66, curd 0.12; total 100 per cent.

CHURNING RECORD.

Pounds of cream	1,313	Size of granules	Navy beans.
Pounds of fat in cream	360	Temperature of buttermilk...°F..	60
Pounds of butter made	430	Test of buttermilk......per cent..	0.8
Per cent of fat in cream	27.4	Temperature of wash water...°F..	55
Pasteurization temperature...°F..	150	Amount of wash water: Same as buttermilk.	
Ripening temperature.......°F..	65	Revolutions in wash water	12
When cooled	2 to 6.30	Rollers in or out of gear	Out.
Temperature when ready to churn, °F	59	Length of time worked......min..	2¼
Kind of churn used	D. No. 4.	Number of revolutions worked	18
Length of time churning....min..	25		

Churn cover closed tight while working the butter.

TABLE 28.—*Composition and churning record of sample No. 553, which has the highest curd content found in the investigation.*

Analysis: Butterfat 81.21, water 13.85, salt 1.52, curd 3.42; total 100 per cent.

CHURNING RECORD.

Pounds of cream	[1] 11,335	Length of time churning....min..	40
Test of cream..........per cent..	30.6	Size of granules	Wheat.
Pounds of fat in cream	[1] 3,476	Temperature of buttermilk...°F..	58
Pounds of butter made	[1] 4,349	Test of buttermilk.....per cent..	0.13
Ripening temperature.......°F..	56	Temperature of wash water...°F..	60
Acidity when ready to churn, per cent	0.7	Amount of wash water......gals..	100
Temperature when ready to churn, °F	57	Revolutions in wash water	10
Kind of churn used	D. No. 6.	Rollers in or out of gear	Out.
		Length of time worked ...min..	5 to 10
		Number of revolutions worked	18

Churn cover closed tight while working the butter.

NAVY BUTTER.

Navy butter, in this article, has reference to the creamery butter made and packed for the Navy Department under the supervision of the Dairy Division, under contract to conform to specifications prepared by the division.

The specifications affecting the composition of the butter read as follows:

> *Butter.*—Shall be fresh butter made during such period of 90 days to be stated in proposal after April 15, 1910, and before August 15, 1910, as shall be most suitable for butter making in the locality of the creamery where it is to be made, from pasteurized milk or cream, none of which shall contain before pasteurization more acid in 50 c. c. than will be neutralized by 15 c. c. or 13 c. c. of N/10 alkali solution, as determined by Mann's acid test, for butter scoring 94 and 95, respectively.

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[1] One day's make, several churnings.

Quality.—Shall be strictly of the grade of creamery extras and must score not less than 94 and 95, respectively, at the time of packing.

Composition.—Moisture in the butter must not exceed 13 per cent. There must be no preservative used other than common salt, and that shall be at a rate giving not less than 2½ per cent or more than 3¼ per cent salt in the butter at time of packing.

Inspection.—The ingredients, manufacture, sanitation, packing, boxing, marking, and shipping of the butter shall be subject to inspection by Government inspectors, who shall have full authority to reject any lot of milk, cream, or the finished butter, or any other requirement which does not conform in every respect to these specifications.

Tests.—The Government inspector shall make all the necessary tests to determine that the acid in the milk or cream and the salt and moisture contents in the butter are within the limits specified.

The samples of Navy butter analyzed in this investigation gave the following results:

TABLE 29.—*Composition of 34 samples of Navy butter.*

Percentage.	Fat.	Water.	Salt.	Curd.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Average	84.13	12.21	2.72	0.94
Highest	85.46	13.09	3.18	1.81
Lowest	82.90	11.19	2.02	.48
Variation	2.56	1.90	1.16	1.33

SAMPLES DIVIDED ACCORDING TO SIZE OF GRANULES AT TIME CHURNING WAS COMPLETED.

Percentage.	Fat.	Water.	Salt.	Curd.
Large granules	84.27	12.10	2.70	0.92
Medium granules	83.69	12.69	2.68	.93
Small granules	84.31	11.93	2.78	.97

TABLE 30.—*Churning conditions of samples of Navy butter.*

Average fat content of cream churned	per cent	31
Average acidity of cream churned	per cent	0.164
Churning temperatures:		
Highest	°F	56
Lowest	°F	46
Average	°F	51
Length of time churned:		
Highest	minutes	120
Lowest	do	30
Average	do	55
Size of granules:		
Small	samples	11
Medium	do	10
Large	do	13
		34

Temperature of wash water:		
Highest	°F	51
Lowest	°F	42
Average	°F	46
Revolutions in wash water (rollers out of gear):		
Highest		12
Lowest		4
Average		9.5
Revolutions butter was worked:		
Highest		33
Lowest		13
Average		22

APPENDIX.

The detailed analyses of all the samples in this investigation are given in the two following tables. Table I records the general samples, and Table II the samples of Navy butter.

Table I.—*Detailed analyses of samples of American creamery butter.*

Number of sample.	Month taken.	Composition.				Amount of butter made.	Test of cream.	Acidity of cream.	Kind of churn used.	Churning time.	Size of granules.[1]	Churning temperature.	Temperature of wash water.	Revolutions in wash water.		Revolutions worked.
		Butterfat.	Moisture.	Salt.	Curd.									Rollers in gear.	Rollers out of gear.	
		Per ct.	*Per ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*P. ct.*	*P. ct.*		*Mins.*		°*F.*	°*F.*			
1	July	79.58	15.37	3.94	1.11	.....	31	0.64	I	100	S	60	60	6	.....	22
2	...do	79.23	15.70	4.36	.71	.....	29	.66	I	95	M	60	60	6	.....	22
3	...do	79.77	15.00	3.96	1.27	.....	25	.....	G	60	S	58	58	.....	12	12
4	...do	80.75	13.66	4.02	1.57	.....	25	.....	G	45	S	59	58	.....	12	12
5	...do	79.40	14.17	5.17	1.26	.....	25	.....	G	35	S	60	58	.....	12	12
7	August	81.00	14.54	3.59	.87	1,010	30	.60	I	58	S	57	66	.....	8	15
11	July	83.25	14.31	1.31	1.13	228	33	.....	I	45	S	50	52	.....	8	.....
12	June	82.00	14.51	2.41	1.08	658	25	.60	I	55	S	58	54	.....	11	11
13	July	81.41	15.02	2.69	.88	504	25	.....	I	35	M	59	48	.....	14	12
14	...do	84.38	12.93	1.88	.81	571	28	.....	I	75	M	48	53	.....	12	22
15	...do	82.14	14.05	1.97	1.84	185	33	.....	I	45	M	55	52	.....	20	15
16	...do	84.13	13.58	1.58	.71	580	31	.....	I	105	M	54	56	.....	12	.....
17	...do	85.98	12.31	1.05	.66	161	.....	.....	I	35	L	52	50	.....	3	14
18	June	79.93	14.76	4.45	.86	732	25	.....	I	30	S	62	58	.....	33	13
19	...do	81.91	14.95	2.28	.86	859	26	.....	I	28	S	62	48	5	.....	.....
20	July	84.25	12.99	1.87	.89	530	24	.....	I	45	M	53	52	.....	8	20
21	...do	80.38	15.85	2.85	.92	2,386	.....	.....	I	30	L	56	50	2	.....	12
22	...do	81.37	14.52	3.34	.77	1,195	.....	.....	O	45	L	56	60	.....	10	25
23	...do	82.86	14.50	1.77	.87	625	27	.....	I	45	M	60	52	.....	20	20
24	...do	82.00	14.19	2.59	1.22	500	.....	.....	B	55	M	50	50	.....	7	18
26	...do	83.07	13.47	2.45	1.01	1,429	26	.....	B	40	M	54	52	.....	4	18
27	...do	82.04	13.11	3.71	1.14	690	28	.....	B	70	L	54	60	.....	10	25
28	...do	85.34	12.46	1.19	1.01	591	29	.....	B	45	M	63	52	.....	30	22
29	...do	80.49	15.28	2.84	1.39	315	.....	.....	B	40	M	54	54	5	.....	18
30	...do	82.74	14.58	1.90	.78	580	.....	.....	I	60	L	52	55	.....	11	14
31	November	80.79	14.22	3.91	1.08	607	22	.....	B	30	M	62	58	.....	15	18
33	December	80.01	14.90	3.52	1.57	2,294	21	.....	E	40	S	60	60	.....	12	22
35	September	79.10	17.56	2.17	1.17	.....	.....	.36	F	60	M	54	52	10	.....	23
40	November	83.78	13.13	1.72	1.37	163	26	.....	I	45	M	60	54	6	.....	20
44	April	84.28	13.41	1.62	.69	896	34	.52	G	35	M	54	55	.....	6	12
47	July	80.23	14.45	4.59	.73	732	26	.50	G	40	S	52	52	.....	3	.....
54	August	84.28	12.33	2.02	1.37	662	29	.54	B	75	L	60	58	.....	2	22
55	...do	80.31	14.36	4.40	.93	600	.....	.....	I	60	S	54	56	.....	15	15
59	...do	84.09	13.10	1.88	.93	629	25½	.65	B	95	L	61	58	.....	6	33
60	...do	83.49	13.22	2.05	1.24	640	27½	.59	B	52	L	60	58	.....	2	22
61	July	80.91	14.76	3.39	.94	650	32	.50	G	40	S	51	48	.....	7	19
63	August	81.85	13.81	3.83	.51	315	.....	.....	G	30	M	57	57	.....	10	20
64a	...do	84.70	12.12	1.89	1.29	336	26	.....	B	50	S	57	58	.....	17	26
72	...do	84.09	12.51	2.77	.63	335	28	.....	B	40	L	57	61	.....	10	17
73	...do	83.27	13.63	1.95	1.15	373	32	.....	I	45	M	50	60	.....	6	9
100a	October	81.98	14.65	2.79	.58	1,240	27½	.....	G	90	S	59	61	.....	71	14
101	...do	82.45	14.07	2.77	.71	1,240	27½	.....	G	50	S	58	58	.....	81	14
105	July	75.68	18.23	5.46	.63	1,183	.....	.....	I	25	L	52	54	10	.....	15
106	...do	80.85	15.19	2.41	1.55	630	35	.....	G	40	M	52	52	.....	8	20
107	...do	82.21	15.20	1.33	1.26	126	22	.....	B	30	M	58	53	.....	6	12
108	...do	83.20	12.48	3.79	.53	910	.....	.49	I	75	M	49	52	.....	20	18
109	...do	84.07	13.02	1.99	.92	389	.....	.....	I	90	M	52	52	.....	10	14
110	...do	79.37	16.65	3.04	.94	424	.....	.....	F	210	S	52	50	.....	10	60
111	...do	84.38	13.50	1.02	1.10	.....	.....	.....	I	45	M	53	52	.....	15	18
112	...do	81.80	14.49	2.94	.77	767	31	.....	I	60	L	58	60	.....	30	12

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[1] The letters in this column stand for small, medium, and large. Granules the size of a grain of wheat and less are called "small"; those as large as a pea or bean are called "medium"; and when larger than a bean they are called "large."

TABLE I.—*Detailed analyses of samples of American creamery butter*—Continued.

Number of sample.	Month taken.	Composition.				Amount of butter made.	Test of cream.	Acidity of cream.	Kind of churn used.	Churning time.	Size of granules.	Churning temperature.	Temperature of wash water.	Revolutions in wash water.		Revolutions worked.
		Butterfat.	Moisture.	Salt.	Curd.									Rollers in gear.	Rollers out of gear.	
		Per ct.	*Per ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*P. ct.*	*P. ct.*		*Mins.*		*°F.*	*°F.*			
115	August....	84.79	12.28	2.24	0.69	182	......	......	B	60	M	53	54	....	.....	22
123	November	82.73	13.90	2.04	1.33	1,560	......	0.36	B	40	S	60	64	14	.....	28
124	...do......	82.27	14.30	2.82	.61	545	19	......	I	60	S	58	59	15	.....	....
126	...do......	81.82	14.07	2.47	1.64	840	25	......	G	70	S	54	54	....	12	....
130	July......	77.92	15.99	5.21	.88	697	22	.47	G	100	M	52	50	....	12	21
132	...do......	78.80	16.42	3.95	.83	700	24	.47	G	100	M	50	50	....	6	17
138	August....	84.85	12.41	2.15	.59	410	......	.52	D	40	S	53	62	....	20	18
139	...do......	82.77	13.60	2.64	.99	453	......	......	D	35	S	53	54	....	11	23
140	...do......	83.28	12.74	2.14	1.84	236	21½	......	I	48	M	52	52	....	5	11
141	...do......	80.28	13.74	5.16	.82	380	......	.50	I	45	M	52	65	....	25	6
142	...do......	81.77	14.00	3.24	.99	440	......	......	I	45	M	58	58	....	100	15
143	July......	84.20	13.60	1.27	.93	415	28	......	B	30	M	61	54	....	10	18
144	...do......	83.22	12.04	3.97	.77	251	27	......	I	35	M	58	59	....	20	18
145	...do......	83.54	13.35	1.91	1.20	723	28	......	B	30	M	61	54	....	12	19
146	August....	81.27	13.88	2.24	2.61	453	26	.65	B	35	M	59	60	....	12	27
147	July......	83.68	14.04	1.79	.49	655	24	......	B	22	S	57	52	....	12	17
153	...do......	82.23	14.31	2.68	.78	712	30½	.37	B	40	L	56	64	....	10	16
154	...do......	81.15	14.78	3.04	1.03	810	41½	.42	I	45	L	54	68	....	6	14
155	...do......	82.25	14.31	2.76	.68	......	......	.55	B	40	L	56	64	....	12	18
156	...do......	81.75	14.45	2.77	1.03	900	......	.52	B	50	L	56	60	....	12	18
157	...do......	78.80	16.83	3.09	1.28	800	......	.43	B	50	L	56	62	....	12	18
158	...do......	82.43	13.78	2.39	1.40	411	......	......	B	35	L	57	50	....	7	19
159	...do......	82.50	14.57	2.30	.63	......	......	......	I	40	M	56	54	....	7	18
160	...do......	81.30	15.05	3.14	.51	......	......	......	B	60	L	55	52	10	.....	24
161	...do......	82.09	14.80	1.53	1.58	......	......	......	I	60	M	55	52	7	.....	30
162	...do......	80.01	15.11	4.21	.67	......	......	.68	B	45	S	54	50	....	12	35
168	December.	83.26	13.13	1.93	1.68	389	24	.68	I	48	M	60	60	....	12	18
169	August....	78.66	15.10	5.14	1.10	424	26	......	I	45	M	56	50	3	7	12
176	...do......	81.62	14.67	2.90	.81	420	22	......	I	35	S	55	52	....	20	12
177	July......	83.31	13.90	1.27	1.52	298	......	......	I	40	S	53	52	....	7	....
178	...do......	81.64	13.49	4.27	.60	360	32	.38	I	40	S	54	50	....	6	9
179	August....	78.82	16.63	3.48	1.07	582	......	......	I	60	M	58	53	....	29	11
180	...do......	84.01	13.65	1.49	.85	780	26	......	E	55	S	55	52	....	5	18
185	October...	84.83	12.65	2.16	.36	607	30	......	D	40	M	58	57	4	.....	15
191	July......	85.16	11.04	2.66	1.14	500	......	.15	B	50	L	52	49	....	10	29
192	August....	82.27	14.09	2.83	.81	......	33	......	G	35	S	59	56	....	8	13
193	...do......	83.38	13.27	2.46	.89	......	27	......	G	35	S	58	57	....	4	11
194	...do......	82.21	14.05	2.81	.93	568	32½	.60	I	35	M	57	61	32	12	23
203	November	84.03	13.52	1.41	1.04	471	......	......	B	45	M	54	54	....	20	20
205	August ...	82.29	13.69	3.10	.92	700	35	......	I	30	L	56	52	....	7	12
206	...do......	84.77	12.86	1.25	1.12	......	......	......	I	60	M	52	52	....	.....	....
207	July......	80.81	15.04	3.19	.96	1,701	......	......	I	50	M	53	52	....	2	14
208	August....	75.21	18.54	4.61	1.64	372	34	......	I	45	S	54	50	....	20	20
209	...do......	81.81	14.59	2.76	.84	1,008	30	......	I	30	M	58	57	....	6	14
210	...do......	81.70	13.66	3.21	1.43	620	25	......	I	35	M	51	53	....	4	8
211	...do......	82.16	15.02	1.28	1.54	693	......	......	I	30	M	56	53	10	.....	10
212	...do......	82.53	14.12	2.07	1.28	155	25	......	I	45	M	51	50	....	10	14
213	...do......	81.83	13.88	2.17	2.12	459	25	......	I	65	S	50	52	10	.....	15
214	...do......	80.25	15.28	3.44	1.03	390	25	......	I	40	M	52	56	....	12	15
220	...do......	83.06	13.48	2.54	.92	......	31	......	G	60	L	64	55	....	8	15
221	...do......	80.87	15.15	2.79	1.19	......	28	......	G	50	L	64	54	....	44	13
222	...do......	82.74	14.05	2.54	.67	1,090	29	......	G	60	L	63	54	....	44	15
236	...do......	84.27	12.24	2.30	1.19	2,068	......	16	D	50	S	54	46	....	12	20
243	...do......	82.70	13.22	2.41	1.67	495	......	......	I	60	S	54	52	12	.....	11
244	...do......	82.88	14.42	1.24	1.46	568	23	......	I	65	M	51	52	....	10	12
247	...do......	84.56	12.98	1.35	1.11	402	25	......	I	45	S	52	53	....	8	14
251	...do......	80.62	15.45	3.06	.87	1,422	31	......	G	45	M	62	53	....	8	16
252	...do......	81.58	14.92	2.74	.76	1,422	30	......	G	30	L	64	52	....	59	15
253	October...	83.76	12.70	1.53	2.01	345	27	.60	B	40	M	58	59	....	4	24
254	...do......	81.17	16.39	1.83	.61	324	32	.55	B	30	M	59	66	15	.....	20
255	January...	83.17	14.04	1.57	1.22	181	24	.45	B	30	M	66	68	....	30	30
257	September	79.13	14.04	5.62	1.21	401	29	......	E	25	M	58	59	....	12	20
258	October...	83.41	13.84	1.45	1.30	310	31	.62	I	40	M	60	58	....	4	15
259	January...	82.44	13.98	2.08	1.50	576	28	.45	B	30	S	61	59	....	10	32
261	...do......	81.15	13.95	3.45	1.45	792	23	.60	B	50	L	61	62	....	30	30
262	October...	83.74	13.46	1.67	1.13	600	25	.58	B	40	M	57	56	....	2	26
263	August....	82.62	14.11	1.87	1.40	587	......	.66	E	30	M	56	50	....	8	30
264	...do......	82.74	13.31	2.60	1.35	844	32	.63	E	50	M	54	50	....	8	33
265	...do......	82.58	14.07	2.31	1.04	493	33½	.64	B	40	M	58	56	....	10	26
266	...do......	86.03	11.49	1.61	.87	326	30	.40	B	30	M	60	54	....	16	22
269	September	84.34	13.80	.92	.94	531	......	......	I	120	S	54	62	....	20	12
270	...do......	77.53	16.79	3.60	2.08	472	......	......	G	45	M	50	52	....	5	20

TABLE I.—*Detailed analyses of samples of American creamery butter*—Continued.

Number of sample.	Month taken.	Composition.				Amount of butter made.	Test of cream.	Acidity of cream.	Kind of churn used.	Churning time.	Size of granules.	Churning temperature.	Temperature of wash water.	Revolutions in wash water.		Revolutions worked.
		Butterfat.	Moisture.	Salt.	Curd.									Rollers in gear.	Rollers out of gear.	
		Per ct.	*Per ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*P. ct.*	*P. ct.*		*Mins.*		*°F.*	*°F.*			
271	September	83.67	13.70	1.39	1.24	286	25	......	E	50	M	59	58	....	22	25
278	July......	80.54	15.36	3.20	.90	800	......	0.23	B	55	L	54	60	....	12	18
279	August....	81.81	14.64	2.46	1.09	712	......	.30	B	50	L	54	60	....	12	18
280	...do......	82.81	13.38	2.89	.92	950	......	.23	B	55	L	54	60	....	12	16
281	...do......	81.99	14.70	2.86	.45	500	......	.29	B	35	S	52	58	....	12	18
282	...do......	81.43	13.88	3.57	1.12	800	......	.25	B	40	L	54	60	....	12	18
283	March.....	83.04	13.18	2.90	.88	600	......	......	B	40	M	58	58	....	12	18
285	August....	80.86	16.43	1.76	.95	840	31	......	I	60	L	53	54	....	12	12
286	November	82.45	13.92	2.36	1.27	772	28	......	I	90	M	56	56	....	10	30
287	August....	82.21	13.99	3.06	.74	748	25	......	I	105	M	56	54	....	12	12
288	...do......	83.36	13.56	2.15	.98	690	......	......	B	45	M	54	50	....	4	28
289	...do......	80.49	14.14	3.20	2.17	630	25	......	I	40	M	52	52	....	12	9
290	...do......	80.27	16.78	1.94	1.01	1,035	30	......	I	30	M	53	53	....	38	15
291	...do......	81.05	15.61	2.42	.92	1,126	......	......	I	60	M	54	52	....	6	16
293	...do......	80.86	14.73	3.62	.79	600	25	......	I	70	M	56	52	....	6	12
295	September	81.34	14.28	2.84	1.54	600	32	......	B	60	M	54	54	26	.....	18
296	October...	82.53	14.84	1.86	.77	600	26	......	B	60	M	54	50	....	6	24
297	...do......	80.67	14.70	3.36	1.27	117	......	......	B	60	M	53	52	....	25	24
298	...do......	82.20	13.78	3.74	.28	560	......	......	I	55	L	54	52	....	30	25
299	...do......	81.22	15.49	2.23	1.06	393	35	.51	I	35	M	50	50	....	10	18
300	August....	80.15	14.88	3.63	1.34	110	......	......	F	20	M	54	56	10	.....	35
301	...do......	84.76	11.97	1.75	1.52	617	25	.64	E	68	M	55	52	....	20	20
302	...do......	82.85	14.42	1.59	1.14	1,000	40	.54	B	15	L	52	52	4	.....	18
303	...do......	82.12	14.05	1.84	1.99	625	25	.59	I	71	M	55	54	....	20	18
304	...do......	82.48	14.00	1.85	1.67	404	30	......	B	35	S	48	50	15	.....	15
305	September	83.38	13.52	1.98	1.12	194	......	.70	I	75	S	54	54	....	22	17
306	October...	85.02	12.21	1.44	1.33	202	......	......	E	30	S	60	53	....	10	20
307	August....	83.34	14.20	1.13	1.33	817	......	......	I	50	M	52	50	....	7	15
308	October...	83.48	12.89	1.53	2.10	222	......	......	E	45	M	58	52	....	17	20
309	...do......	81.24	14.54	2.93	1.29	450	26	......	I	45	M	53	54	....	6	12
311	August....	82.96	13.29	1.44	2.31	285	......	......	F	30	S	58	56	10	.....	....
312	...do......	82.30	14.20	1.85	1.65	656	25	......	I	55	L	55	55	....	6	10
313	...do......	84.33	13.55	.99	1.13	470	......	......	I	60	L	56	52	8	.....	16
314	...do......	81.13	14.90	2.79	1.18	419	28	......	I	70	M	58	52	....	30	15
315	September	83.64	13.72	1.35	1.29	200	25	......	E	45	M	58	52	....	10	20
316	...do......	83.96	12.70	1.60	1.74	1,000	......	......	E	60	L	51	56	....	10	15
317	...do......	81.51	15.29	1.73	1.47	265	......	......	I	45	M	57	60	10	12	10
318	October...	80.73	14.18	4.05	1.04	600	33	......	B	60	M	57	56	....	10	25
319	August....	82.41	14.60	2.36	.63	449	30½	......	B	60	L	56	54	....	10	25
322	September	79.71	13.74	4.11	2.44	429	30	......	H	60	L	57	55	....	12	72
323	August....	80.27	15.14	2.41	2.18	705	29	......	G	60	L	57	62	....	66	13
324	...do......	79.75	13.64	4.09	2.52	560	27	......	G	120	M	63	58	....	9	18
326	September	81.86	14.76	2.16	1.22	......	26	......	G	16	S	63	61	....	5	12
327	...do......	78.98	13.92	4.14	2.96	207	24	.45	H	65	S	56	62	....	13	105
328	August....	81.98	14.22	2.50	1.30	4,400	29½	......	G	40	M	66	60	....	.....	12
329	...do......	84.93	12.65	1.90	.52	......	33	......	G	40	M	61	43	....	4	13
330	...do......	83.00	14.48	1.19	1.33	......	......	.69	G	30	M	65	58	....	83	9
331	...do......	81.59	14.32	2.70	1.39	......	32	......	G	40	S	60	42	....	4	14
332	...do......	81.78	13.78	2.79	1.65	......	34	......	G	45	M	60	44	....	4	13
334	...do......	78.72	14.60	3.27	3.41	......	30	......	G	20	S	58	45	....	5	16
335	...do......	79.78	14.87	2.74	2.61	......	31	.65	G	60	L	64	59	....	82	15
337	...do......	81.77	12.70	3.78	1.75	......	27½	......	B	50	M	61	68	....	27	15
338	...do......	82.68	13.56	2.79	.97	......	37	......	G	30	S	61	56	....	20	20
339	...do......	83.19	12.62	3.01	1.18	......	32½	.50	G	40	M	65	59	....	85	15
340	...do......	86.91	11.13	.94	1.02	......	27	......	B	60	S	62	67	....	30	15
360	September	80.45	15.03	2.56	1.96	506	30	......	I	45	S	54	50	2	.....	11
361	...do......	77.64	16.61	4.47	1.28	500	32	......	B	50	S	56	64	....	2	15
364	August....	80.80	14.30	3.24	1.66	950	......	.29	B	55	L	54	62	....	12	18
365	...do......	78.78	16.39	4.06	.77	1,050	......	.28	B	70	L	54	60	....	12	18
369	...do......	82.65	13.10	3.14	1.11	1,000	......	.28	B	60	L	54	58	....	12	18
370	September	83.08	13.09	3.20	.63	385	28	......	G	60	S	55	58	....	20	24
371	August....	81.67	13.84	3.21	1.28	450	......	.29	B	20	L	54	58	....	12	18
372	...do......	81.93	14.15	2.89	1.03	900	......	.27	B	30	S	52	58	....	12	18
373	October...	83.51	13.83	1.46	1.20	325	......	......	B	20	S	55	58	....	3	14
374	...do......	79.46	15.11	4.93	.50	700	......	......	I	60	S	56	60	....	9	12
375	...do......	82.63	13.90	2.60	.87	567	......	......	B	30	S	56	56	....	5	22
381	September	81.84	15.25	1.82	1.09	560	......	......	E	60	M	50	56	....	12	18
383	...do......	82.69	13.94	2.21	1.16	291	......	......	I	40	L	54	54	....	10	13
384	August....	80.96	13.57	4.32	1.15	545	......	......	D	60	L	53	51	9	.....	24
385	September	84.06	13.20	1.37	1.37	582	22	......	I	45	S	52	58	....	10	10
386	...do......	82.35	13.89	2.61	1.15	700	......	......	I	60	M	56	52	....	10	14
387	...do......	81.74	14.31	3.07	.88	623	23	......	B	75	L	58	58	....	12	27

TABLE I.—*Detailed analyses of samples of American creamery butter*—Continued.

Number of sample.	Month taken.	Composition.				Amount of butter made.	Test of cream.	Acidity of cream.	Kind of churn used.	Churning time.	Size of granules.	Churning temperature.	Temperature of wash water.	Revolutions in wash water.		Revolutions worked.
		Butterfat.	Moisture.	Salt.	Curd.									Rollers in gear.	Rollers out of gear.	
		Per ct.	*Per ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*P. ct.*	*P. ct.*		*Mins.*		*°F.*	*°F.*			
388	August....	82.41	13.09	3.38	1.12	632	23	......	I	60	M	56	51	....	4	26
389	...do.......	81.93	13.65	3.34	1.08	236	......	......	I	30	M	56	52	2	13	12
390	...do.......	78.89	14.54	5.24	1.33	515	......	......	I	25	L	57	54	....	10	20
391	September	81.39	15.70	1.41	1.50	530	......	......	I	40	M	57	63	8	.....	8
393	...do.......	77.09	16.52	5.26	1.13	750	......	0.56	I	30	L	56	61	5	1	15
394	...do.......	85.51	12.89	.95	.65	407	......	......	D	40	S	....	52	....	4	15
395	August....	83.54	12.98	2.07	1.41	498	......	.54	I	45	M	48	54	....	20	24
396	...do.......	84.37	12.15	1.64	1.84	365	......	.42	I	75	M	50	56	....	10	....
397	September	83.43	13.75	1.81	1.01	395	......	......	G	70	M	54	52	....	10	12
398	August....	83.38	13.73	2.00	.89	395	......	......	I	20	L	54	54	....	12	13
399	...do.......	82.52	13.50	2.75	1.23	620	......	......	I	40	S	....	52	....	10	19
400	...do.......	81.89	12.45	3.71	1.95	550	23	......	I	30.	S	56	54	....	8	22
401	...do.......	80.95	13.78	3.36	1.91	467	......	......	I	35	S	50	54	4	.....	16
403	...do.......	82.55	14.12	2.37	.96	500	......	......	I	35	L	56	58	....	6	10
404	...do.......	81.60	14.41	2.64	1.35	445	......	......	I	35	L	56	51	....	18	18
405	...do.......	83.80	13.18	.97	2.05	423	31	......	B	35	S	58	58	....	2	25
407	...do.......	83.88	13.59	.99	1.54	199	22½	.50	B	35	S	60	62	....	20	25
408	September	79.08	15.25	4.48	1.19	965	......	......	E	70	L	57	66	....	35	45
409	...do.......	81.32	14.30	2.43	1.95	499	......	.40	B	48	L	60	59	....	2	26
410	August....	85.01	12.07	1.73	1.19	586	27	......	B	20	M	62	52	....	12	18
411	...do.......	81.95	13.63	3.20	1.22	530	26	.60	B	45	L	61	53	....	8	18
412	...do.......	84.22	13.35	.78	1.65	375	31	......	B	30	S	59	58	....		25
413	...do.......	83.03	13.89	1.98	1.10	635	27½	......	B	18	L	63	54	....	11	10
414	September	78.65	16.12	4.06	1.17	856	......	......	E	75	L	57	66	....	35	37
415	August....	82.92	14.17	1.70	1.21	354	25	.65	B	28	M	61	62	....	14	25
416	...do.......	83.21	13.67	1.68	1.44	423	27½	......	B	25	S	63	56	....	10	27
417	...do.......	84.62	13.60	1.66	.12	430	27	......	B	25	L	60	55	....	12	18
418	...do.......	83.45	13.52	1.61	1.42	566	29	......	B	55	M	60	60	....	7	20
419	...do.......	84.60	13.14	1.24	1.02	426	32	.60	B	40	L	54	60	....	10	15
420	September	80.31	15.05	3.82	.82	992	......	......	E	85	L	57	66	....	35	45
421	August....	84.01	12.76	1.95	1.28	424	26½	.60	B	33	S	61	62	....	20	28
422	...do.......	83.28	13.17	1.91	1.64	414	24	.60	B	45	S	59	62	....	25	25
423	September	83.96	13.25	2.01	.78	541	......	......	B	43	L	60	59	....	2	26
424	August....	83.31	12.85	1.24	2.60	833	26	......	B	45	L	61	53	....	8	18
425	...do.......	83.41	13.46	2.61	.52	572	25	.50	B	80	S	61	63	....	15	15
426	September	83.60	13.12	2.09	1.19	571	30	......	B	71	S	58	57	....	2	32
427	August....	83.45	13.62	1.92	1.01	428	27	......	B	23	M	60	55	....	10	18
428	...do.......	86.60	11.51	.98	.91	423	31	......	B	30	S	58	58	....	2	25
429	...do.......	83.23	13.65	2.12	1.00	418	24	.20	B	35	S	63	61	....	20	23
436	September	83.43	13.19	2.46	.92	420	......	......	I	60	L	54	65	2	6	10
437	...do.......	81.87	13.05	3.03	2.05	531	30	......	B	60	S	55	56	7	.....	20
439	...do.......	75.93	16.75	5.98	1.34	370	27	......	G	40	M	52	53	....	10	18
445	...do.......	81.85	13.87	2.43	1.85	618	25	......	B	40	M	62	60	12	.....	12
455	August....	81.06	14.98	1.72	2.24	239	33	......	E	55	M	54	63	....	10	21
456	September	80.96	14.09	2.04	2.91	423	31	.34	B	45	....	52	62	....	10	20
457	...do.......	83.51	12.74	1.59	2.16	202	30	.68	B	25	M	59	61	....	7	20
458	...do.......	82.34	14.14	1.44	2.08	600	27	.65	B	40	M	58	65	10	.....	25
459	August....	83.48	13.06	1.45	2.01	116	30	.65	B	45	S	62	58	....	10	28
461	...do.......	84.46	12.16	1.83	1.55	415	32	.55	E	50	M	57	62	....	10	24
462	October...	81.57	13.15	2.24	3.04	403	28	.65	I	60	S	56	64	....	5	12
463	August....	83.20	13.80	1.54	1.46	655	35	.60	B	33	S	56	60	....	25	25
464	October...	85.36	11.59	1.09	1.96	1,050	27	.55	B	75	M	55	58	....	10	14
435	...do.......	81.32	14.08	3.43	1.17	870	29	.60	I	60	S	58	72	3	12	20
466	August....	80.40	13.82	4.59	1.19	818	27½	.67	I	35	M	56	62	....	25	15
467	...do.......	81.37	13.97	3.42	1.24	773	......	.59	B	45	S	59	64	....	45	25
468	...do.......	83.30	13.99	1.36	1.35	345	26	......	B	60	M	54	54	....	15	19
469	September	82.02	14.17	2.36	1.45	583	30	.50	B	40	S	58	58	....	10	28
470	...do.......	82.82	13.16	2.28	1.74	567	32	.60	B	45	M	54	58	....	8	25
471	...do.......	82.27	13.58	2.77	1.38	720	26	.65	B	35	M	62	60	....	12	26
472	...do.......	84.01	13.09	1.82	1.08	651	32½	......	B	75	M	59	62	....	25	18
473	...do.......	83.46	13.13	2.03	1.38	528	30	.58	B	75	M	55	56	5	.....	29
474	...do.......	85.02	12.07	1.85	1.06	617	32	.50	B	60	S	58	54	....	10	20
475	August....	81.18	13.67	3.62	1.53	550	29	.65	B	55	S	55	48*	....	10	30
476	...do.......	83.12	13.97	1.43	1.48	564	22	.68	I	40	M	60	62	....	5	19
477	September	84.48	13.19	1.14	1.19	420	29	.68	I	60	M	57	58	....	20	14
479	August....	81.51	15.53	1.85	1.11	477	30	.61	E	40	L	60	64	15	.....	25
480	September	82.10	14.24	2.33	1.33	253	......	......	E	40	M	56	54	....	7	20
481	...do.......	80.30	14.63	3.63	1.44	790	......	......	B	60	M	54	50	....	5	18
482	October...	82.54	14.03	2.09	1.34	1.546	......	......	B	75	M	56	56	....	10	25
483	September	81.18	14.04	3.03	1.75	657	......	......	B	60	L	55	54	....	10	22
485	August....	79.80	15.11	2.66	2.43	311	......	......	B	40	M	56	52	....	8	25
486	October...	84.37	11.86	.76	3.01	364	30	......	B	45	M	58	60	....	26	18

TABLE I.—*Detailed analyses of samples of American creamery butter*—Continued.

Number of sample.	Month taken.	Composition.				Amount of butter made.	Test of cream.	Acidity of cream.	Kind of churn used.	Churning time.	Size of granules.	Churning temperature.	Temperature of wash water.	Revolutions in wash water.		Revolutions worked.
		Butterfat.	Moisture.	Salt.	Curd.									Rollers in gear.	Rollers out of gear.	
		Per ct.	*Per ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*P. ct.*	*P. ct.*		*Mins.*		°*F.*	°*F.*			
487	October...	83.44	13.25	2.21	1.10	504	......	......	B	45	M	57	56	....	10	14
488	...do.......	84.99	12.73	1.37	.91	256	......	......	B	40	S	54	50	....	8	21
489	November	82.02	14.80	1.72	1.46	624	21	......	B	90	M	62	58	....	15	14
490	August....	84.10	12.17	2.37	1.36	583	......	......	B	50	M	56	58	....	12	24
491	March.....	82.09	14.15	2.14	1.62	591	......	......	E	60	S	52	59	10	.....	28
492	February .	84.28	12.59	1.96	1.17	186	24	......	B	45	M	58	56	....	14	....
493	March.....	83.30	13.52	1.80	1.38	......	27	......	B	35	M	56	60	....	20	24
494	...do......	80.90	15.05	2.67	1.38	524	25	......	I	90	M	59	62	5	.....	28
495	...do......	83.23	13.62	1.78	1.37	463	25	......	B	90	M	59	62	4	6	24
496	...do......	80.64	13.12	2.92	3.32	630	38	0.35	B	35	M	55	55	....	6	30
497	...do......	81.53	14.77	2.32	1.38	519	36	......	B	90	M	58	62	12	.....	24
498	...do......	83.36	13.43	1.85	1.36	598	22	......	B	60	S	....	60	....	8	25
499	...do......	83.11	12.66	2.20	2.03	388	24	......	I	45	S	60	60	....	8	20
500	...do......	84.36	12.29	1.98	1.37	500	......	......	B	45	S	57	54	....	7	20
501	...do......	82.11	12.80	3.02	2.07	635	28	......	B	60	M	54	52	10	.....	25
502	...do......	83.56	13.33	1.51	1.60	563	......	......	I	90	M	58	60	....	10	14
503	...do......	87.39	10.13	1.76	.72	410	......	......	I	45	M	58	....	....	5	22
504	April......	80.97	14.61	3.57	.85	879	25	......	I	20	L	57	58	4	6	22
507	May.......	80.87	16.19	1.64	1.30	......	......	......	B	35	S	64	68	....	9	10
518	April......	84.06	10.95	4.29	.70	178	24	.27	B	25	M	54	60	....	8	64
519	...do......	83.88	13.14	1.79	1.19	290	25	.34	B	15	M	52	56	....	7	62
524	September	81.01	14.64	3.57	.78	504	28	......	I	19	M	61	52	....	16	24
525	May.......	81.45	15.40	2.48	.67	582	27	......	E	45	S	58	54	....	10	20
526	October...	82.94	13.39	1.79	1.98	166	24	.55	B	60	S	54	49	13	.....	17
537	September	81.89	13.92	2.72	1.47	683	27	.50	B	55	S	56	57	....	10	25
538	October...	79.82	14.36	3.32	2.50	795	31	......	E	30	S	57	57	....	.....	28
541	August....	83.34	13.37	1.53	1.76	313	34	.45	B	35	S	54	58	....	20	25
549	September	78.87	15.01	2.95	3.17	384	33	.65	B	40	S	49	58	....	25	40
551	October...	82.46	13.43	2.26	1.85	310	30	......	B	35	M	56	60	....	25	28
552	September	81.81	13.34	3.17	1.68	834	28	.52	B	45	S	54	54	....	12	30
553	...do......	81.21	13.85	1.52	3.42	[1]4,349	30	.70	B	40	S	58	60	....	10	18
556	October...	78.79	15.64	3.28	2.29	675	27	.51	G	40	....	54	52	....	18	18
562	...do......	80.78	14.84	2.69	1.69	240	30	......	B	27	M	53	53	....	18	22
563	November	83.34	13.72	1.04	1.90	182	25½	......	B	30	M	58	50	....	5	25
564	December.	80.75	14.53	2.91	1.81	290	......	......	B	90	S	58	58	....	12	25
565	November	80.11	14.61	2.06	3.22	404	28½	......	B	70	M	57	60	....	5	30
566	...do......	79.74	14.67	2.34	3.25	630	24	......	I	45	S	62	56	....	20	19
567	December.	84.25	12.37	1.71	1.67	645	30	......	E	60	M	60	59	....	6	20
568	...do......	82.33	13.92	2.52	1.23	570	25½	......	B	35	L	60	60	15	5	25
569	...do......	78.43	16.34	3.58	1.65	545	......	.71	E	105	S	58	57	....	10	9
570	...do......	81.25	14.71	2.24	1.80	610	......	.71	E	60	S	59	59	....	10	22
571	...do......	82.14	13.49	3.24	1.13	208	32	.43	C	30	L	56	56	....	20	20
572	September	78.74	15.46	4.04	1.76	750	29	......	B	25	L	54	55	10	.....	25
573	...do......	79.66	17.49	1.15	1.70	692	......	......	I	60	M	52	58	....	10	13
574	...do......	84.01	11.18	3.80	1.01	390	......	......	E	40	M	56	52	....	32	24
575	...do......	82.42	13.92	2.57	1.09	570	28	......	B	30	S	58	54	....	25	20
576	...do......	82.20	14.26	1.23	2.31	260	......	......	E	45	S	58	52	....	10	20
580	...do......	82.79	13.60	2.27	1.34	700	......	......	I	75	M	56	56	....	15	16
581	...do......	82.99	13.23	2.66	1.12	540	25	......	B	45	S	56	62	3	2	27
583	...do......	80.96	13.88	3.74	1.42	948	......	......	I	200	L	56	56	....	7	20
585	October...	80.90	14.59	2.98	1.53	640	28	.60	B	35	L	58	56	5	2	25
587	September	80.29	14.45	3.27	1.99	......	......	.40	B	50	L	59	66	....	12	18
589	...do......	81.24	14.21	3.29	1.26	614	......	......	I	70	M	56	56	2	8	19
590	...do......	81.34	13.82	3.81	1.03	......	......	.30	B	50	L	60	66	....	12	18
591	...do......	81.79	13.82	3.31	1.08	445	27	.60	B	17	L	61	56	7	.....	20
592	November	84.74	12.58	1.77	.91	654	26	......	B	70	S	59	60	....	12	20
593	September	83.65	13.61	1.18	1.56	118	35	.52	B	40	S	60	61	....	20	14
594	October...	84.71	13.78	.82	.69	62	34	.60	B	35	S	61	62	....	18	16
615	April......	85.92	11.45	2.40	.23	945	25	......	B	45	S	62	52	....	12	9
616	...do......	85.43	12.02	1.69	.86	630	20	......	B	30	L	61	61	....	12	13
618	...do......	83.34	12.82	2.84	1.00	450	......	......	B	45	S	54	54	....	4	28
619	...do......	85.75	11.90	1.50	.85	548	......	......	B	40	M	60	58	....	10	28
620	...do......	85.21	11.65	2.35	.79	352	......	......	B	35	M	58	46	25	.....	25
621	...do......	84.22	13.22	1.83	.73	184	......	......	C	30	S	59	60	20	.....	20
622	November	82.75	14.44	1.41	1.40	168	29	......	I	45	S	57	63	....	20	25
623	May.......	83.88	12.72	3.10	.30	568	43	......	B	40	M	55	58	....	12	32
624	April......	82.85	13.81	2.47	.87	449	......	......	I	30	M	58	60	8	.....	16
625	...do......	84.11	13.67	1.04	1.18	599	25	......	E	45	S	58	58	....	3	28
626	...do......	86.32	10.76	2.22	.70	409	......	......	B	......	S	52	60	....	16	24
628	October...	85.58	11.04	2.37	1.01	115	......	......	G	35	S	58	67	....	6	14

[1] One day's make, several churnings.

TABLE I.—*Detailed analyses of samples of American creamery butter*—Continued.

Number of sample.	Month taken.	Composition.				Amount of butter made.	Test of cream.	Acidity of cream.	Kind of churn used.	Churning time.	Size of granules.	Churning temperature.	Temperature of wash water.	Revolutions in wash water.		Revolutions worked.
		Butterfat.	Moisture.	Salt.	Curd.									Rollers in gear.	Rollers out of gear.	
		Per ct.	*Per ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*P. ct.*	*P. ct.*		*Mins.*		°*F.*	°*F.*			
630	October...	84.30	12.34	1.03	2.33	465	28½	...	I	50	S	61	65	...	4	16
631	April......	83.34	13.90	2.24	.52	133	24	...	I	25	S	62	60	...	8	16
632	October...	82.79	14.51	1.65	1.05	330	...	...	I	45	L	58	75	...	8	14
633	February.	80.76	14.38	3.66	1.20	800	28	...	B	45	L	58	64	...	15	20
634	December.	81.48	14.71	2.55	1.26	840	36	...	G	45	M	53	53	...	56	20
635	January...	81.82	14.22	2.90	1.06	...	29	...	G	90	M	57	58	10	8	8
637	...do......	79.55	15.72	2.73	2.00	1,050	29	...	G	35	...	63	58	8	7	14
639	December.	81.66	14.52	2.45	1.37	791	32	...	G	40	M	53	52	...	56	15
640	January...	81.39	15.02	2.30	1.29	860	...	...	H	...	...	58	61	...	75	40
643	April......	84.16	11.55	2.30	1.99	340	...	...	E	30	S	60	60	...	26	16
644	...do......	82.99	12.96	2.18	1.87	1,030	...	...	B	60	S	57	56	...	16	30
645	December.	83.89	12.60	2.02	1.49	318	24	...	B	30	M	60	60	...	34	35
646	...do......	82.88	13.33	2.59	1.20	553	23	...	B	45	M	61	60	...	25	35
647	...do......	81.88	13.79	2.27	2.06	645	25	...	B	47	S	61	59	...	34	45
648	April......	83.98	12.28	3.13	.61	650	...	...	I	60	S	60	62	...	22	12
649	October...	80.97	14.37	3.02	1.64	550	...	...	I	60	M	56	56	...	7	...
650	...do......	81.26	13.46	4.04	1.24	786	...	...	I	60	S	56	58	...	12	14
651	...do......	81.02	14.72	3.25	1.01	746	...	...	I	60	M	50	55	...	12	...
652	...do......	83.23	13.68	2.01	1.08	533	...	...	I	60	L	52	56	...	15	17
653	...do......	83.74	13.49	1.51	1.26	214	...	...	I	40	M	54	56	...	16	14
654	...do......	84.04	12.60	2.07	1.29	520	27	...	I	60	M	58	55	...	10	18
656	September	82.96	13.72	1.72	1.60	...	...	...	I	45	S	56	56	...	10	4
657	...do......	82.80	14.27	1.72	1.21	530	...	...	I	42	S	54	55	2	8	12
658	...do......	84.09	13.59	1.06	1.26	478	26½	...	D	60	M	56	56	...	6	14
659	October...	82.60	13.59	2.08	1.73	587	22	...	I	40	S	55	53	6	...	10
660	...do......	80.70	13.78	4.20	1.32	567	...	...	I	40	M	53	56	...	15	12
662	September	82.57	13.73	2.63	1.07	203	28	0.60	I	28	S	56	55	...	10	16
667	April......	82.92	12.91	3.50	.67	275	...	...	I	30	M	62	64	...	15	12
668	...do......	84.72	11.87	2.13	1.28	...	...	...	I	20	M	61	65	...	6	14
669	March.....	80.35	15.19	3.68	.78	497	30	...	E	30	M	54	56	10	5	26
670	April......	83.79	13.05	2.50	.66	375	32	...	I	25	M	58	60	...	15	12
671	May.......	85.31	11.90	1.72	1.07	140	...	...	G	55	S	51	60	...	8	25
673	...do......	81.84	14.62	2.60	.94	...	...	.80	I	30	S	58	50	...	5	...
674	January...	83.62	13.85	1.42	1.11	315	30	...	I	20	S	64	66	...	6	4
675	May.......	77.95	17.28	3.83	.94	493	32	.56	I	30	M	62	56	...	4	14
678	April......	84.36	13.16	1.63	.85	700	...	...	B	60	S	56	56	...	12	30
679	...do......	81.68	14.46	2.56	1.30	598	...	...	E	60	S	54	56	...	7	22
680	November	81.58	14.11	2.96	1.35	673	25½	...	B	40	M	58	60	...	14	25
681	April......	84.13	12.44	2.76	.67	232	...	.54	B	30	S	50	56	21	...	32
682	...do......	85.49	12.20	1.37	.94	471	...	...	B	30	M	58	60	10	...	30
683	...do......	85.03	12.91	1.77	.29	670	...	...	B	40	...	60	58	...	10	24
684	December.	81.88	13.74	2.81	1.57	718	24	...	B	120	M	61	60	...	40	42
685	April......	83.45	13.54	1.85	1.16	945	25	...	B	45	S	62	52	...	12	9
686	October...	82.49	13.20	3.07	1.24	372	26	.65	B	40	S	58	60	...	8	25
687	...do......	82.75	13.75	2.50	1.00	550	33	.55	I	50	M	55	57	...	20	15
688	...do......	78.22	16.97	3.33	1.48	261	25	.65	B	40	M	58	62	...	15	15
689	...do......	81.92	13.64	3.27	1.17	846	29	.58	I	45	L	56	54	...	10	18
690	...do......	83.27	11.63	3.93	1.17	160	22	.70	I	35	M	56	60	...	30	15
691	...do......	85.05	12.87	1.30	.78	106	28	.60	I	20	S	58	60	...	10	12
692	...do......	81.17	13.32	4.30	1.21	770	33	...	B	40	M	57	60	...	10	28
693	...do......	82.51	14.35	1.48	1.66	740	30	.60	I	60	M	58	54	...	6	14
694	...do......	81.83	14.89	2.12	1.16	392	33	.75	I	30	S	57	68	...	4	18
695	...do......	84.69	12.42	1.76	1.13	315	26	.55	B	40	M	59	58	...	6	20
696	March....	78.40	15.80	4.62	1.18	318	...	...	E	40	S	56	53	...	12	44
697	February.	83.87	12.80	2.38	.95	775	...	...	B	35	L	62	61	...	16	26
698	...do......	81.27	15.26	2.42	1.05	600	...	...	I	60	M	60	64	...	12	25
700	...do......	81.28	15.56	2.48	.68	740	...	...	I	60	L	61	58	...	13	14
701	January...	79.27	16.17	3.41	1.15	725	31	...	I	90	L	59	60	12	40	25
702	...do......	82.44	13.64	2.94	.98	177	26½	.59	G	40	L	58	60	...	10	20
704	...do......	83.96	12.45	2.83	.76	319	28	.51	C	45	M	56	56	...	20	30
705	February.	84.56	11.84	2.60	1.00	400	...	...	B	45	M	58	58	...	15	...
706	November	81.21	13.18	4.71	.90	308	30	...	I	60	M	58	60	...	15	18
707	April......	81.11	14.75	2.21	1.93	386	30	.50	B	30	S	58	59	...	15	28
708	November	79.45	15.55	3.46	1.54	680	20	...	I	120	M	52	57	...	8	11
710	...do......	82.74	13.10	2.89	1.27	670	22	...	E	...	M	56	58	...	14	...
711	...do......	80.61	15.10	3.38	.91	400	...	...	I	50	M	56	60	...	8	...
712	...do......	84.79	10.93	2.38	1.90	314	...	...	I	105	L	56	54	...	10	10
713	...do......	84.64	12.80	1.41	1.15	750	...	...	G	30	M	62	63	...	6	...
716	...do......	82.80	11.90	4.12	1.18	428	32	.49	A	60	S	60	52	...	...	...
717	December.	80.48	15.92	1.70	1.90	183	17	...	G	35	M	62	60	...	12	...
723	January...	82.18	14.57	1.89	1.36	648	27	.52	B	40	S	62	68	...	15	29
724	...do......	83.03	13.07	2.45	1.45	395	28	.52	B	35	L	64	64	...	12	24

TABLE I.—*Detailed analyses of samples of American creamery butter*—Continued.

Number of sample.	Month taken.	Composition.				Amount of butter made.	Test of cream.	Acidity of cream.	Kind of churn used.	Churning time.	Size of granules.	Churning temperature.	Temperature of wash water.	Revolutions in wash water.		Revolutions worked.
		Butterfat.	Moisture.	Salt.	Curd.									Rollers in gear.	Rollers out of gear.	
		Per ct.	*Per ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*P. ct.*	*P. ct.*		*Mins.*		*°F.*	*°F.*			
725	November	81.47	12.94	4.57	1.02	569	30	......	E	80	M	56	62	....	9	26
726	...do......	83.68	12.72	1.98	1.62	327	35	0.50	I	35	M	56	58	....	6	19
727	...do......	83.16	13.09	1.89	1.86	324	27	.60	I	55	S	56	56	....	15	10
728	January...	83.80	12.15	2.96	1.10	468	30	.55	B	85	S	58	60	....	6	28
729	...do......	82.70	13.08	2.17	2.05	280	30	.50	B	40	S	56	66	....	8	28
730	November	86.36	12.02	.68	.94	218	28	.58	E	60	M	62	62	....	12	15
731	...do......	84.73	12.48	1.70	1.09	127	31	.65	B	65	S	55	58	....	30	30
732	...do......	83.31	13.44	1.77	1.48	432	27	.50	B	60	M	59	57	....	6	16
733	...do......	80.76	15.32	2.48	1.44	150	25	.51	C	64	S	59	62	....	25	30
734	...do......	83.62	12.98	2.07	1.33	782	27	......	I	75	M	57	58	....	25	18
735	...do......	84.12	12.73	2.03	1.12	284	30	......	I	45	M	56	60	....	10	15
736	January...	83.30	13.48	1.93	1.29	522	23	.57	B	48	M	55	57	....	4	18
737	December.	82.91	13.23	2.82	1.04	975	28	.55	B	40	L	62	62	....	8	29
738	November	81.45	15.14	2.22	1.19	133	28	.52	C	35	M	61	61	....	15	32
739	...do......	82.35	13.93	2.33	1.39	160	24	.21	I	45	S	62	62	....	15	18
740	December.	82.38	13.80	2.80	1.02	149	29	.53	C	25	S	58	60	....	10	25
741	November	82.39	13.82	2.85	.94	145	22	.56	C	40	L	60	58	....	15	25
742	...do......	78.77	14.77	5.65	.81	266	27½	.25	E	30	M	60	60	....	10	23
743	...do......	80.16	15.76	2.29	1.79	198	22½	.62	E	70	S	62	62	....	15	17
744	January...	84.42	12.18	2.43	.97	330	27	.50	E	30	S	60	65	....	25	24
745	December.	81.67	13.99	3.36	.98	230	28	.59	I	38	S	58	63	....	24	24
746	...do......	83.83	12.63	2.62	.92	685	25	......	B	55	S	60	56	....	12	24
747	...do......	82.47	13.66	2.09	1.78	256	......	......	I	35	S	57	63	....	28	33
748	...do......	81.18	13.68	3.66	1.48	249	27	.43	I	47	S	56	63	....	24	31
749	...do......	81.07	13.93	2.30	2.70	230	28	.50	I	40	L	58	63	....	30	35
750	...do.......	80.72	15.70	1.95	1.63	429	......	......	I	120	M	59	59	10	.....	10
751	...do.......	80.24	15.16	3.81	.79	750	......	......	I	130	M	55	58	15	.....	18
752	...do	77.77	15.52	5.25	1.46	785	......	.58	I	60	M	60	59	8	.....	14
753	...do.......	82.79	13.27	2.25	1.69	620	......	......	B	60	S	54	65	....	12	....
754	...do.......	82.17	14.38	2.19	1.26	720	......	......	I	45	S	56	68	....	16	13
756	...do.......	83.47	12.51	2.60	1.42	386	26	......	I	45	S	54	60	....	11	12
757	...do.......	82.54	14.00	2.29	1.17	680	26	......	I	30	M	60	60	....	12	11
758	...do.......	80.49	14.59	3.08	1.84	490	......	......	I	75	M	56	66	....	14	14
759	...do.......	80.20	15.49	2.94	1.37	275	......	......	I	24	M	60	62	9	.....	14
760	...do.......	80.72	14.07	3.90	1.31	835	27	......	I	40	M	60	58	5	.....	18
761	...do.......	82.32	11.56	4.76	1.36	246	......	......	I	60	M	60	62	....	10	9
762	February .	82.83	12.36	3.63	1.18	310	29	.50	I	25	S	55	61	....	10	10
763	January...	84.11	13.37	1.47	1.05	209	28	.54	B	45	S	56	63	....	10	27
764	February .	80.33	14.15	4.36	1.16	454	26	.58	I	40	M	56	66	....	20	18
765	March.....	84.02	12.33	2.44	1.21	242	28	.60	I	30	S	62	60	....	10	16
766	February .	84.11	12.28	2.97	.64	567	29	.50	B	35	M	61	63	6	.....	28
767	May.......	84.83	12.72	1.57	.88	541	29	......	B	25	S	58	60	....	12	18
768	February .	80.94	14.81	3.25	1.00	398	30	......	D	40	M	60	62	....	15	21
769	March.....	84.60	12.94	1.45	1.01	435	25	.55	B	30	M	60	62	....	14	25
770	February .	80.41	16.23	2.15	1.21	791	29	.60	E	40	M	60	59	12	.....	15
771	...do.......	84.13	13.07	2.16	.64	407	27½	......	B	40	S	55	60	....	10	25
773	March.....	83.10	14.25	2.01	.64	220	......	......	I	90	S	60	60	....	7	16
775	...do.......	84.86	13.22	1.35	.57	336	30	......	I	30	M	60	50	4	3	12
776	...do.......	81.93	15.35	2.15	.57	2,031	......	......	I	30	S	56	57	....	20	20
777	...do.......	83.39	13.36	1.75	1.50	980	33	......	G	30	L	58	59	....	40	12
778	...do.......	83.47	13.84	2.04	.65	618	26	.35	I	40	M	58	58	....	.....	10
779	...do.......	81.95	15.54	1.73	.78	217	......	......	G	25	L	62	60	5	20	....
780	...do.......	81.95	14.30	2.80	.95	700	......	......	G	60	M	50	54	6	8	10
781	...do.......	82.45	14.05	2.15	1.35	750	26	.75	I	75	M	57	53	....	5	48
783	...do.......	83.29	14.54	1.67	.50	600	36	......	G	50	S	58	58	....	.....	14
784	...do.......	73.49	20.65	5.14	.72	600	30	......	G	60	S	50	64	....	4	....
785	May.......	81.80	15.41	1.65	1.14	500	35	.55	G	50	M	56	56	....	14	16
786	March.....	85.72	11.10	2.38	.80	750	35	......	G	60	S	57	56	....	10	....
787	...do.......	82.21	15.08	2.22	.49	520	28	......	B	40	M	50	56	15	.....	25
788	...do.......	82.88	14.78	1.65	.69	850	31	......	G	75	S	50	54	....	16	....
790	...do.......	79.68	16.38	3.03	.91	2,000	28	......	G	45	M	59	57	....	.....	15
791	April......	81.12	15.55	2.43	.90	280	33	......	I	40	L	60	58	....	8	20
792	March.....	83.97	14.22	1.34	.47	323	......	......	G	30	L	56	55	....	35	20
793	April......	84.51	13.34	1.53	.62	1,037	36	......	I	30	S	60	62	....	12	....
794	March.....	82.08	15.72	2.75	.45	825	30	......	G	75	M	55	50	....	112	12
795	...do.......	80.98	14.20	2.81	1.01	650	30	......	G	45	M	58	54	....	15	....
798	June.......	83.13	13.83	1.90	1.14	380	25½	......	B	30	S	59	62	....	12	24
799	April......	84.28	13.71	1.22	.79	274	30	.58	I	10	M	64	64	....	5	15
800	May.......	81.45	15.11	2.13	1.31	1,610	25	......	B	35	M	55	53	....	6	23
801	April......	84.08	13.72	1.86	.34	1,256	28	.50	B	40	S	60	60	....	25	25
802	May.......	83.69	12.72	2.62	.97	321	25	......	B	19	M	56	60	....	5	24
803	April......	83.24	13.52	2.21	1.03	545	28	.56	B	35	M	56	60	....	25	20

TABLE I.—*Detailed analyses of samples of American creamery butter*—Continued.

Number of sample.	Month taken.	Composition.				Amount of butter made.	Test of cream.	Acidity of cream.	Kind of churn used.	Churning time.	Size of granules.	Churning temperature.	Temperature of wash water.	Revolutions in wash water.		Revolutions worked.
		Butterfat.	Moisture.	Salt.	Curd.									Rollers in gear.	Rollers out of gear.	
		Per ct.	*Per ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*P. ct.*	*P. ct.*		*Mins.*		°*F.*	°*F.*			
804	May	83.69	12.69	2.28	1.34	648	25	0.60	I	45	S	56	56	....	20	12
805	April	85.62	11.82	1.46	1.10	568	25	.60	I	40	S	60	68	....	50	16
806	May	81.31	14.39	2.91	1.39	307	27	.60	I	30	M	58	56	....	15	16
807	April	84.33	13.74	.99	.94	336	28	.60	I	30	M	59	62	....	10	14
808	May	82.82	14.44	1.52	1.22	658	28	.56	B	30	M	58	62	....	15	25
809	April	82.58	13.52	3.09	.81	789	26	......	I	60	M	56	68	....	30	25
810	...do	81.75	14.07	3.35	.83	380	25	.33	E	50	S	55	56	....	14	34
811	...do	85.40	10.72	3.06	.82	874	24	......	I	95	S	58	60	....	10	26
812	...do	83.47	14.16	1.28	1.09	550	24	......	I	30	M	58	58	....	8	16
813	May	80.06	15.57	3.26	1.11	475	22	......	B	35	S	56	49	....	6	26
814	...do	81.52	14.97	2.44	1.07	800	30	.59	I	25	M	54	50	2	.....	11
815	...do	84.08	13.19	1.65	1.08	431	22	......	E	30	M	54	54	....	12	18
816	June	81.13	14.91	2.80	1.16	700	30	......	I	45	M	50	52	7	.....	10
817	May	82.81	14.16	1.64	1.39	383	29	......	B	25	M	58	52	....	18	40
818	April	84.83	13.51	1.13	.53	450	25	......	I	35	M	54	52	....	16	9
819	June	80.81	14.85	3.93	.41	591	......	......	I	45	M	60	54	4	14	14
820	May	81.50	15.88	2.05	.57	600	32	......	I	45	S	51	54	....	8	14
823	...do	83.09	13.49	2.71	.71	500	27	......	B	35	M	58	56	....	13	26
824	June	80.69	16.14	2.04	1.13	870	32	......	E	40	L	52	54	....	12	21
825	...do	80.84	15.24	2.71	1.21	750	32	......	I	70	L	52	50	....	6	10
826	May	82.36	14.18	2.35	1.11	441	23	......	I	45	S	55	51	....	11	11
827	June	78.14	15.12	5.96	.78	1,075	30	......	E	40	L	58	50	....	14	34
828	May	82.30	14.25	2.08	1.37	504	29	......	I	35	M	54	52	....	8	11
829	April	80.80	14.37	3.94	.89	618	24	......	B	40	M	58	58	6	.....	30
830	...do	82.15	14.78	2.26	.81	663	23	.50	I	60	M	57	56	29	.....	24
831	May	82.48	13.94	2.26	1.32	660	32	.64	I	60	M	53	53	....	2	12
832	...do	83.49	15.06	.94	.51	350	......	......	I	50	L	53	50	5	3	14
834	...do	83.57	13.71	1.67	1.05	840	23	......	I	40	M	59	56	9	.....	18
835	...do	83.74	14.10	1.45	.71	1,488	22	......	I	40	M	55	52	7	.....	16
843	...do	86.08	11.47	1.55	.90	308	......	......	I	45	M	58	60	....	7	20
852	March	84.37	13.09	2.34	.20	373	24	......	I	45	M	56	58	....	15	20
854	...do	82.52	13.50	3.23	.75	475	24	.50	I	35	M	55	56	....	7	15
862	April	83.03	13.92	2.19	.86	242	33	......	B	30	M	54	65	....	7	33
869	March	81.16	14.26	4.19	.39	567	30	.57	B	75	S	51	56	3	.....	23
870	May	82.65	14.92	1.47	.96	471	28	.54	B	30	L	52	60	20	.....	35
873	...do	79.24	15.48	4.02	1.26	640	25	.54	I	40	S	54	54	....	15	9
876	April	78.80	15.66	4.13	1.41	525	32	......	I	30	L	60	60	3	.....	18
878	...do	84.77	12.66	1.49	1.08	669	31	......	I	50	M	59	60	2	.....	12
879	...do	81.27	14.65	3.03	1.05	562	29	.66	B	40	M	57	62	5	10	....
882	...do	82.42	14.31	2.25	1.02	763	27	......	I	40	L	56	58	....	9	16
910	June	82.77	13.86	2.30	1.07	1,851	24	......	B	45	S	56	56	....	7	17
914	May	80.44	15.12	2.61	1.83	496	......	......	B	80	S	58	58	....	10	24
917	April	82.25	12.65	3.83	1.27	785	......	......	B	55	S	61	57	....	16	25
923	...do	78.91	17.13	2.31	1.65	603	27	......	I	70	S	56	52	9	.....	25
924	...do	83.27	14.19	1.84	.70	431	25	......	E	40	M	55	64	....	6	18
925	June	84.07	12.81	2.63	.49	632	25	......	B	45	M	54	54	....	5	25
926	...do	82.23	14.84	2.20	.73	615	26	......	E	40	M	52	52	....	10	20
928	July	82.57	14.38	2.51	.54	256	29	......	B	35	M	58	60	11	.....	27
929	April	80.52	14.73	3.85	.90	953	26	......	B	65	S	58	62	....	16	33
930	...do	83.18	13.73	1.57	1.52	333	29	......	I	45	M	54	59	....	3	15
931	May	83.78	13.53	1.73	.96	640	24	......	B	45	M	53	48	....	8	28
935	...do	83.88	13.90	1.34	.88	628	......	......	D	30	M	56	60	....	6	30
936	April	84.02	13.12	1.80	1.06	179	......	......	B	40	S	56	52	....	5	25
939	June	82.67	14.21	2.08	1.04	1,000	......	.63	B	60	M	54	50	....	10	25
940	April	81.39	13.80	4.13	.68	590	......	......	B	30	M	56	53	20	.....	40
942	...do	83.65	13.38	2.04	.93	399	......	......	B	30	M	56	60	....	10	25
944	June	84.45	11.72	3.19	.64	292	35	.45	I	50	S	53	59	....	4	26
952	May	82.31	14.22	2.17	1.30	855	24	......	C	80	M	57	57	....	6	....
955	July	81.93	14.49	3.04	.54	672	35	.45	I	45	M	51	62	20	.....	15
958	...do	81.64	14.66	2.73	.97	920	38	.60	I	45	M	54	58	....	10	30
960	...do	83.67	14.38	1.29	.66	270	35	......	C	45	S	54	53	....	7	22
991	April	82.53	14.50	1.91	1.06	1,136	24	......	B	40	M	57	59	....	8	23
1041	...do	81.36	14.42	2.78	1.44	415	29	.50	G	50	S	54	52	....	10	18
1044	...do	83.51	12.47	3.25	.77	315	31	......	G	20	M	54	54	....	6	23
1050	...do	85.64	11.72	1.51	1.13	594	40	......	G	33	M	53	56	....	5	25
1052	...do	80.91	15.31	2.25	1.53	364	44	......	G	20	M	60	64	....	3	3
1058	...do	83.55	12.85	2.42	1.18	504	......	......	G	30	M	60	52	....	5	18
1059	...do	81.24	15.03	2.40	1.33	500	27	.58	I	35	S	54	53	....	10	24
1060	...do	83.66	12.66	2.78	.90	385	......	......	B	65	S	49	56	....	9	29
1066	...do	83.92	12.86	1.77	1.45	654	30	.55	B	30	S	58	58	....	10	32
1070	...do	84.07	11.98	2.23	1.72	900	......	.55	G	48	S	54	58	....	6	19
1072	...do	84.12	13.21	1.35	1.32	456	20	......	E	60	S	61	59	....	6	16

TABLE I.—*Detailed analyses of samples of American creamery butter*—Continued.

Number of sample.	Month taken.	Composition.				Amount of butter made.	Test of cream.	Acidity of cream.	Kind of churn used.	Churning time.	Size of granules.	Churning temperature.	Temperature of wash water.	Revolutions in wash water.		Revolutions worked.
		Butterfat.	Moisture.	Salt.	Curd.									Rollers in gear.	Rollers out of gear.	
		Per ct.	*Per ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*P. ct.*	*P. ct.*		*Mins.*		*°F.*	*°F.*			
1073	April	84.19	13.42	1.37	1.02	699	......	0.57	G	30	S	57	53	....	5	15
1077	...do	83.26	13.46	1.83	1.45	694	38	.54	G	55	S	54	59	....	8	15
1078	...do	79.88	14.73	4.74	.65	322	......	......	B	60	S	60	58	....	6	28
1080	...do	84.06	13.34	1.72	.88	586	......	.50	I	32	S	56	58	....	3	12
1082	...do	85.11	12.33	1.85	.71	4[illegible]0	35	.50	I	35	S	54	54	....	25	14
1084	...do	79.77	16.88	2.75	.60	434	......	......	B	30	S	58	60	....	12	24
1086	...do	84.56	12.61	1.40	1.43	653	24	.70	B	45	S	55	58	....	9	19
1087	...do	82.80	13.22	3.00	.98	822	36	......	I	25	S	58	50	....	12	25
1089	...do	84.73	12.49	1.87	.91	348	35	......	......	30	S	60	54	....	8	30
1091	...do	82.66	13.80	2.55	.99	625	19	.48	I	30	S	53	54	6	....	16
1092	May	83.26	13.53	2.05	1.16	800	21	......	I	40	S	57	54	....	6	....
1093	...do	83.30	13.48	2.32	.90	756	......	......	I	40	M	56	60	....	12	8
1094	...do	81.83	13.73	3.10	1.34	468	26	......	I	45	M	56	56	....	8	14
1095	April	86.09	11.23	1.90	.78	515	......	......	I	45	M	58	56	....	15	12
1096	...do	83.50	12.59	3.20	.71	496	26	......	I	30	S	58	60	....	12	18
1098	...do	83.50	13.29	2.28	.93	780	25	......	I	35	M	60	55	....	18	14
1101	...do	86.24	10.52	2.27	.97	620	......	......	G	35	S	61	55	....	5	....
1102	...do	85.88	11.84	1.52	.76	......	......	......	I	45	M	56	58	....	10	....
1105	...do	83.76	13.35	2.08	.81	285	......	......	G	45	M	51	53	....	8	17
1106	...do	81.45	14.19	3.28	1.08	670	26	......	I	240	M	58	54	....	6	17
1107	...do	80.59	15.07	3.24	1.10	60	28	......	I	45	S	58	55	....	2	12
1109	...do	85.16	11.75	2.05	1.04	200	......	......	I	45	L	56	52	....	6	....
1110	...do	81.62	14.74	2.62	1.02	600	......	......	E	75	....	54	59	....	12	21
1111	May	84.90	11.50	2.36	1.24	725	32	......	G	55	S	60	50	....	4	16
1112	...do	80.90	16.47	2.01	.62	282	......	......	G	30	M	64	56	....	8	....
1113	...do	79.89	15.16	4.02	.93	700	35	......	I	30	M	56	56	5	5	32
1114	...do	83.62	12.69	2.87	.82	600	30	......	G	45	M	59	57	....	40	36
1115	...do	83.30	13.72	2.27	.71	400	35	......	G	30	M	58	....	....	5	30
1116	...do	82.78	13.69	2.23	1.30	475	30	......	I	45	M	60	58	....	12	....
1117	June	83.08	13.85	2.13	.94	800	30	......	G	60	M	58	58	....	2	10
1118	May	82.61	14.03	2.32	1.04	492	26	......	G	50	M	58	62	....	....	23
1119	...do	81.76	13.75	3.26	1.23	578	33	......	G	60	M	57	59	....	62	12
1123	...do	83.55	13.34	2.17	.94	384	33	......	G	45	S	52	54	....	7	30
1124	April	82.86	13.24	2.67	1.23	1,670	31	.60	G	60	S	56	54	15	....	25
1126	May	82.83	15.17	1.56	.44	348	30	......	B	45	M	59	60	....	32	8
1127	...do	83.59	12.15	3.35	.91	700	30	.50	I	35	S	61	62	....	10	12
1128	...do	85.92	10.66	2.25	1.17	460	32	......	G	60	S	60	56	....	15	26
1129	...do	83.02	13.43	2.42	1.13	430	......	......	G	30	S	60	56	....	10	30
1130	April	78.29	18.65	1.96	1.10	1,912	31	.60	G	60	M	58	58	....	....	12
1131	May	79.85	15.10	3.84	1.21	580	22	......	E	30	S	54	56	....	15	22
1132	...do	84.47	13.35	1.30	.88	380	27	......	I	45	S	55	56	....	7	9
1133	...do	80.11	14.55	4.52	.82	475	20	......	I	50	S	58	53	....	20	18
1136	...do	82.98	12.30	4.05	.67	540	......	......	I	45	S	56	60	....	10	12
1137	...do	82.09	13.94	2.73	1.24	500	......	......	I	40	M	58	58	....	10	18
1138	April	86.75	10.55	1.85	.85	596	25	......	B	75	M	56	56	....	14	....
1139	May	83.40	13.03	2.75	.82	690	25	......	B	45	M	55	58	....	18	24
1140	...do	84.72	13.09	1.96	.23	760	25	......	B	45	M	57	60	....	8	22
1141	...do	83.23	13.93	1.95	.89	756	28	......	B	45	M	60	59	....	10	28
1142	...do	83.31	13.29	2.61	.79	495	20	.52	I	45	S	58	58	....	10	12
1143	June	84.02	13.60	1.88	.50	700	35	......	I	50	M	60	60	....	11	10
1145	...do	84.19	13.47	2.01	.33	500	30	......	B	30	M	55	55	11	....	25
1147	...do	82.94	13.33	2.59	1.14	120	32	......	G	25	M	58	58	....	20	16
1154	...do	86.56	11.64	1.34	.46	667	......	......	G	30	S	54	51	....	8	21
1155	...do	83.44	13.05	2.66	.85	435	28	......	G	45	S	58	58	....	20	12
1157	...do	80.29	15.55	3.30	.86	592	......	......	G	25	M	58	60	....	33	17
1158	July	83.23	14.01	1.70	1.06	820	30	......	G	......	S	56	67	....	10	....
1160	June	79.75	16.39	3.19	.67	750	......	......	B	60	M	56	57	....	11	10
1161	...do	82.34	13.19	3.68	.79	360	33	.55	G	60	M	58	58	16	3	30
1163	April	83.13	14.00	1.54	1.33	199	21	......	B	18	M	60	62	16	....	20
1164	May	83.25	14.53	1.34	.88	800	......	......	E	30	S	57	50	....	10	22
1165	...do	82.05	12.95	4.52	.48	631	25	......	B	35	S	56	54	....	6	18
1175	April	83.58	12.05	3.55	.82	225	21	......	B	40	S	56	56	3	6	24
1190	July	80.26	15.73	3.14	.87	661	30	.50	B	45	M	56	55	8	5	15
1193	...do	83.42	14.13	1.92	.53	116	26	......	G	50	S	52	53	....	3	14
1194	May	81.52	13.00	4.21	1.27	372	31	......	I	18	L	58	58	....	6	9
1195	June	80.90	14.48	3.44	1.18	307	25	......	B	22	L	60	58	....	6	32
1198	July	84.17	12.93	2.42	.48	185	25	......	C	45	M	56	56	....	35	120
1205	June	82.11	14.93	2.30	.66	590	31	......	C	45	M	55	55	5	....	24
1206	July	83.04	13.39	3.10	.47	863	29	......	I	45	L	58	54	....	12	12
1207	...do	81.08	14.66	3.44	.82	728	24	......	I	45	M	56	51	....	15	14
1208	June	82.50	14.89	1.40	1.21	1,362	30	......	I	40	M	55	52	....	3	18
1209	...do	82.46	14.70	2.54	.30	620	25	......	B	40	M	53	52	....	4	22

TABLE II.—*Detailed analyses of samples of Navy butter.*

Number of sample.	Month taken.	Composition.				Amount of butter made.	Test of cream.	Acidity of cream.	Kind of churn used.	Churning time.	Size of granules.[1]	Churning temperature.	Temperature of wash water.	Revolutions in wash water.		Revolutions worked.
		Butterfat.	Moisture.	Salt.	Curd.									Rollers in gear.	Rollers out of gear.	
		Per ct.	*Per ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*P. ct.*	*P. ct.*		*Mins.*		°*F.*	°*F.*			
46	July.......	83.31	13.06	2.62	1.01	1,610	35	0.15	G	60	M	48	42	....	6	16
48	...do.......	83.63	12.86	2.46	1.05	936	34	.19	G	60	S	46	42	....	6	16
49	...do.......	83.17	13.09	2.61	1.13	864	34	.19	G	45	M	48	44	....	7	18
51	...do.......	82.90	13.03	2.95	1.12	760	29	.19	G	60	M	48	44	....	7	16
52	...do.......	83.30	12.76	3.01	.93	730	33	.19	G	40	M	50	42	....	6	15
53	...do.......	84.04	12.57	2.64	.75	940	33	.18	G	50	M	50	42	....	8	16
56	August....	84.84	11.46	2.87	.83	1,660	29	.14	D	60	S	52	46	....	12	20
64	...do.......	84.73	11.82	2.68	.77	1,687	28	.14	D	40	S	52	46	....	12	25
65	July.......	83.35	12.63	2.56	1.46	1,333	27	.16	D	50	S	52	46	....	12	20
80	August....	84.89	11.32	2.41	1.38	1,846	28	.17	D	75	S	52	46	....	12	20
128	July.......	83.81	12.83	2.49	.87	1,656	33	.16	G	45	M	50	46	....	4	16
129	...do.......	82.97	13.01	2.88	1.14	756	33	.16	G	50	M	48	42	....	6	17
131	...do.......	84.40	12.12	2.96	.52	1,554	31	.21	G	50	S	48	42	....	4	16
133	...do.......	83.51	11.84	2.84	1.81	1,822	28	.15	D	45	S	51	46	....	12	25
134	...do.......	84.75	11.66	3.11	.48	1,561	27	.19	D	40	S	52	46	....	12	20
135	...do.......	85.18	11.19	2.95	.68	1,785	28	.18	D	40	S	51	46	....	12	20
136	...do.......	84.62	11.97	2.81	.60	1,748	29	.14	D	40	S	51	46	....	12	20
149	...do.......	83.62	12.75	2.95	.68	574	......	.14	B	30	L	53	49	....	10	26
150	...do.......	83.10	12.92	3.18	.80	660	......	.14	B	30	L	56	49	....	10	26
151	...do.......	84.33	12.20	2.71	.76	520	......	.15	B	45	L	52	49	....	10	25
187	...do.......	84.37	12.50	2.38	.75	....	......	.12	B	60	L	52	49	....	10	30
188	...do.......	84.41	11.95	2.02	1.62	....	......	.15	B	45	L	52	48	....	10	28
189	...do.......	84.36	12.14	2.87	.63	....	......	.15	B	45	L	52	48	....	12	26
190	...do.......	83.60	12.31	3.09	1.00	520	......	.15	B	45	L	52	49	....	10	28
223	...do.......	83.55	12.31	2.91	1.23	525	......	.14	B	45	L	53	50	....	10	29
224	August....	84.06	12.20	3.07	.67	300	......	.14	B	45	L	52	49	....	10	26
225	...do.......	84.85	11.33	2.70	1.12	450	......	.13	B	60	L	52	50	....	12	27
227	...do.......	84.96	11.59	2.53	.92	480	......	.26	B	120	L	50	50	....	10	28
356	...do.......	83.59	12.36	2.91	1.14	406	......	.31	B	60	S	54	48	....	10	25
357	...do.......	83.79	12.40	2.99	.82	455	......	.14	I	120	M	51	48	....	10	14
358	...do.......	85.38	11.53	2.33	.76	420	......	.13	B	45	L	52	48	....	10	26
359	...do.......	85.01	11.53	2.46	1.00	450	......	.13	B	60	L	50	50	....	12	33
368	...do.......	85.46	11.49	2.14	.91	650	......	.15	B	120	M	51	48	....	10	26
1201	July.......	84.16	12.70	2.48	.66	1,278	43	.18	G	50	M	55	51	....	5	13
	Average.	84.13	12.21	2.72	.94	....	31	.164	.....	55	....	51	46	....	9.4	22

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[1] The letters in this column stand for small, medium, and large. Granules the size of a grain of wheat and less are called "small"; those as large as a pea or bean are called "medium"; and when larger than a bean they are called "large."

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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 150.

A. D. MELVIN, CHIEF OF BUREAU.

THE BACTERIOLOGY OF CHEDDAR CHEESE.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., May 24, 1912.

Sir: I have the honor to transmit for publication in the bulletin series of the bureau the accompanying manuscript entitled "The Bacteriology of Cheddar Cheese," by Messrs. E. G. Hastings and E. B. Hart, of the Wisconsin Agricultural Experiment Station, and Miss Alice C. Evans, of the Dairy Division of this bureau.

Cooperative work on the factors concerned in the ripening of Cheddar cheese has for several years been carried on at Madison, Wis., between the Dairy Division and the Wisconsin Experiment Station, and this bulletin is one of a series in which the results of the work are detailed. Previous experiments have already been described in Bulletin 122 of the Bureau of Animal Industry, entitled "Factors Controlling the Moisture Content of Cheese Curds," and in Bulletins 7 and 11 of the Wisconsin Station.

In connection with the present study credit is due to Mr. L. D. Bushnell, now with the Kansas Agricultural Experiment Station, and Mr. Alfred Larsen, of the North Dakota State Hygiene Laboratory, who were formerly bacteriologists in the Dairy Division and while thus engaged prepared a portion of the data presented in this bulletin.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE BACTERIOLOGY OF CHEDDAR CHEESE.

INTRODUCTION.

The rôle of microorganisms in the preparation and ripening of the various kinds of cheese is a problem that has attracted the attention of bacteriologists since the beginning of the science and since the establishment of the importance of microorganisms in all decomposition processes. From the same raw materials—cow's milk, salt, and rennet, which is an extract of the fourth stomach of the young calf—a great number of varieties of cheese are prepared. These cheeses differ not only in texture, but more especially in flavor and aroma. From what is known of the importance of microorganisms in the preparation of the products of the fermentation industries it is evident to one who gives consideration to the question that undoubtedly microorganisms are as essential in the making of cheese as they are known to be in the preparation of wine, beer, and other products.

In the making of wine and beer the desired changes are produced by a single form of life, the true yeasts, and in the preparation of any desired type of product attention need only be directed as far as the causal organism is concerned in order to insure the presence of the particular variety of yeast that has been found by experience to form a product that has the desired properties as well as to insure the absence of harmful forms. In the preparation of still other products of the fermentation industries not only a single form of life is essential to produce the desired changes, but two or more are needed, one of which may work on a certain constituent of the raw material, the other on another, or the one may serve to make conditions favorable for the growth of the second, usually by the preparation of suitable food.

It is evident that as the number of kinds of microorganisms that are needed to produce the desired changes in any product increases, the complexity of the problem of demonstrating the rôle of each of them is also greatly increased, and it may become most difficult to prove even whether any particular organism is absolutely essential in the preparation of the product, to say nothing of demonstrating its exact rôle. It is not to be supposed that a single form of life is responsible for the complex chemical changes that occur in the ripening of any particular variety of cheese, but rather that a considerable number will be involved.

The fermentation industries include those in which microorganisms are essential for the production of the desired decomposition changes. In all such industries the quality of the product will depend on the raw material and the organisms that are used in the decomposition of that material. The preparation of cheese has not until recent years been classed as a fermentation industry, although it is one in which microorganisms play a dominant rôle. Here, as in all other similar industries, if control of the quality of the product is to be obtained, knowledge must be gained concerning the essential biological agents. In this paper are presented a summary of the present knowledge of the bacteriology of Cheddar cheese and the results of a detailed study of a number of cheeses.

THE BACTERIAL FLORA OF MILK.

In the case of many of the products of the fermentation industries the essential microorganisms are contained in the raw materials, and the development of the methods of preparation of the products have been wholly empirical. Especially is this true of certain kinds of cheese, the methods of manufacture of which are in some cases centuries old. Even in the case of cheese to which at some stage in manufacture material containing certain microorganisms is added the methods of manufacture antedate the science of bacteriology.

The sources from which microorganisms enter the milk are much the same in all parts of the world. Any natural source, such as the interior of the udder, the dust from the animal, or even the utensils, will always furnish certain definite types of microorganisms. By this is not meant that the flora of milk will always include these definite types and no others, but that certain forms will always be present. That this is true is shown by the fact that a sample of ordinary market milk, if stored at temperatures ranging from 60° to 90° F., will undergo a definite sequence of decomposition changes with almost unerring certainty. In this sequence three main groups of microorganisms are prominent; first, the acid-forming bacteria that change the milk into an acid, semisolid mass, favorable for the development of the mold that is characteristic of milk—*Oidium lactis*. This mold, by its gradual destruction of the acid and the establishment of an alkaline reaction, makes it possible for the putrefactive organisms to develop. When the environment is changed this sequence of microbial life in the milk is also changed. For example, milk may be kept at such low temperatures that the acid-forming bacteria can not grow and the putrefactive bacteria appear first.

It is thus proper to speak of a characteristic milk flora. By some it is believed that this flora is so constant that fermentations that depart from the normal are to be looked upon not as due to the introduction of other forms of microorganisms, but most often to changes in the properties of the organisms or to changes in environment that favor the particular organisms which produce the abnormal fermentation. Slight changes in the composition of the milk may also have a determining influence.

As has been stated, the microorganisms necessary for the preparation of most kinds of cheese are contained in the milk. Whether one form or the other is to develop in the cheese depends upon the environment established by the cheese maker. The manufacture of cheese is thus a problem in the ecology of microorganisms.

DIFFERENCES IN COMPOSITION OF CHEESE.

The differences due to the methods of manufacture result in differences in composition of the cheese at the time it begins to undergo the ripening process, which is to determine whether the cheese is to be classed as one kind or another. The differences in composition of the fresh cheese are very largely in the amount of moisture present. Since the water that is left in the cheese is whey, carrying in solution sugar and other constituents of milk, the effect of differences in moisture is not only in influencing the texture, but also the composition of the cheese. The difference in moisture content between Cheddar and Camembert cheese is approximately 25 per cent. If it is supposed that the moisture of the cheese will have about the same sugar content as milk, this means that the sugar content of the Camembert cheese will be about 1 per cent greater than Cheddar; and since the sugar is all fermented, differences in sugar content ultimately result in differences in acidity.

One of the basal differences between Cheddar and Swiss cheese is that during the making of the first—that is, the operations before pressing—a large amount of acid is formed in the curd, while in the case of Swiss no such acid production occurs. Van Slyke and Hart,[1] Boekhout and Ott de Vries,[2] and Van Dam[3] have shown that acid is held chemically by the proteins of cheese, while sugar is not. Thus if in the making of one cheese acid is formed, and in another not formed, the result will be a somewhat different composition, even though the moisture content of the two cheeses is initially the same.

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[1] Van Slyke, L. L., and Hart, E. B. A study of some of the salts formed by casein and paracasein with acids: Their relations to American Cheddar cheese. New York Agricultural Experiment Station Bulletin 214. Geneva, July, 1902. See p. 60.

[2] Boekhout, F. W. J., and Ott de Vries, J. J. Über den Käsefehler "Kurz" (Kort). Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, Abteilung 2, vol. 24, No. 5/7, pp. 122–129. Jena, Aug. 2, 1909.

[3] Van Dam, W. Über die Konsistenz der Käsemasse bei Edamkäsen. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, Abteilung 2, vol. 32, No. 1/2, pp. 7–40. Jena, Dec. 5, 1911.

Another difference in composition of cheese is caused by variations in the amount of salt and in the time at which it is added. This difference is an important one in the case of Cheddar and Swiss cheese. These differences in the initial composition are sufficient to exert a great influence on the types of life that are to grow in and on the cheese.

THE ENZYM CONTENT OF CHEESE.

The rôle of the inherent enzyms of milk and those of the rennet extract in the ripening of cheese have been emphasized by the work of Babcock and Russell and of Von Freudenreich and Jensen. There remains no doubt concerning the importance of certain enzyms, especially those of rennet extract, in the ripening of cheese. The enzymic content of all cheese must be much the same qualitatively, since they are made from the same raw materials. Again, it is difficult to see how one enzym can be active in one cheese and not in other kinds, since the conditions are quite similar as regards reaction and other factors. Accepting the theory of the specificity of enzyms, it must be admitted that the products of the activity of any enzym will be the same in kind no matter what the conditions under which it may be working. Hence it does not seem that the enzyms of milk or rennet can be factors determining the kind of cheese to be made by any method from the ordinary raw materials, but that the determining factors must be biological.

BIOLOGICAL PROBLEMS.

The methods of manufacture of cheese result in an environment that causes certain of the organisms constantly present in milk to develop in a definite sequence. The empirical methods of the cheesemaker result in a cheese that approximates, if it is not identical with, the normal of its kind.

Each of the great commercial varieties of cheese thus presents a distinct problem for the bacteriologist, who should be able to demonstrate the constant presence of the essential groups of bacteria. It can not be expected here any more than in most decomposition processes that a single specific organism will be concerned, as in the causation of disease, but rather that groups of organisms will be present, the basis of grouping being largely biochemical. Neither can it be expected that one group will grow for a period, then disappear and be followed by a second, but rather that the sequence of development will be confused.

The work of Thom on Camembert cheese furnishes an excellent illustration. It has been shown that a definite balance between the various forms of life concerned is essential for the normal ripening of this cheese. If through methods of manufacture or through conditions of ripening this balance is destroyed, the cheese will not be typical.

The biological factors concerned in the ripening of Camembert cheese are the acid-forming bacteria, the Camembert mold (*Penicillium camemberti*), or its white form (*Penicillium camemberti* var. *rogeri*); *Oidium lactis;* and bacteria which together with *Oidium lactis* form a reddish slime on the surface of the cheese. If conditions favor the growth of *Oidium* lactis at the expense of the penicillium, the cheese will not be normal; if the mold is too luxuriant, texture is obtained but flavor is not. It is thus evident in the case of Camembert cheese too wide variations in the balance between the different forms of life can not occur if a cheese normal in texture and flavor is to be obtained. A large amount of work has been done on Camembert cheese and the necessity for the presence of the different forms established, but their exact rôle has not been shown and never can be until the chemist devises means of following in detail the complex chemical changes.

It is not only necessary that the constant presence of any organism in cheese be demonstrated in order to prove its importance in the ripening, but it must also be present in sufficient numbers so that it is certain that growth has taken place in the cheese. The simple presence of any form is no evidence of its activity. Such an error was made by Duclaux, one of the first bacteriologists to occupy himself with cheese problems. Since there are such a multitude of forms of bacteria in milk, and hence in cheese, any particular method of examination of the cheese is likely to bring some one group of organisms to the front. The methods used by Duclaux in his examination of Cantal cheese were fitted to favor the development of the spore-bearing, liquefying bacteria. Their constant presence, together with the fact that they produced in pure culture in milk compounds which he had already demonstrated in the ripe cheese, led him to consider them an important factor in the ripening of this cheese. It has been demonstrated since that the conditions in hard cheese do not permit this class of bacteria to develop.

BACTERIOLOGICAL METHODS.

The modern bacteriological methods are not such as will demonstrate the presence of all kinds of bacteria in milk, cheese, or any other substance in which a considerable number of kinds of bacteria are present, even though all may find conditions that will permit of growth on the medium employed. It is usually easy to demonstrate the presence of the form that occurs in greatest numbers, since in the more lightly inoculated culture plates this form will be present in pure culture or else so freed from competition with the other forms that its growth will not be prevented. For those forms present in less numbers this condition does not obtain, and usually special methods must be employed to demonstrate their presence, such as the use of differentiating media or enrichment cultures. Anyone who has much experience in plating milk on lactose media has noted that in certain cases the plates thickly seeded show colonies of but a single organism, usually the ordinary lactic organism *Bacterium lactis acidi*, while on the more thinly seeded plates from the same sample other forms may appear. In the thickly seeded plates the lactic organisms, on account of favorable conditions, have grown most rapidly and by the acid produced have prevented the development of other forms, while in the more thinly seeded plates the colonies may be separated by such a distance that the products of one colony do not reach the others, each colony then grows as though it were the only colony on the plate. Hence forms appear on thinly seeded plates that do not on those crowded with colonies. If the organism that finds most favorable conditions greatly exceeds in numbers some other form the latter may never appear on the culture or be so inconstant as not to attract the attention of the bacteriologist. A ratio of 1,000 to 1 or even 500 to 1 may prevent the detection, by use of the ordinary plate-culture methods, of the organisms present in smaller numbers. This statement may serve to explain the results obtained by previous investigators of Cheddar cheese.

Before 1896 no consecutive bacteriological examinations had been made of a ripening Cheddar cheese. The first detailed work on this variety of cheese with which the writers are acquainted is that of Russell.[1] This work was largely concerned with a quantitative examination of the cheese during the ripening process by means of gelatin plates. It established the fact that acid-forming organisms make up 99 per cent and over of the bacteria thus determined. It may be inferred that the acid-forming bacteria belonged to the *Bacterium lactis acidi* group. The work of Lloyd on English Cheddar cheese led to similar results. The most extensive work on the bacterial flora of Cheddar cheese is that of Harding and Prucha,[2] who isolated the different types of organisms appearing on cultures made from 9 normal Cheddar cheeses during the entire period of ripening. The more than 300 cultures thus isolated were studied in detail and reduced to 33 groups. Of these 33 groups 4 belonged to the *Bacterium lactis acidi* group, the only one which was always found, and it practically always included over 99 per cent of the total germ content. The 10 other groups which these investigators classed as important on account of frequency of occurrence were not found in all of the cheeses, and it may be inferred that they do not represent essential factors in the ripening of Cheddar cheese. In speaking of one cheese the authors say:

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[1] Russell, H. L. The rise and fall of bacteria in Cheddar cheese. Wisconsin Agricultural Experiment Station, Thirteenth Annual Report, pp. 95–111. Madison, 1896.

[2] Harding, H. A., and Prucha, M. J. The bacterial flora of Cheddar cheese. New York Agricultural Experiment Station, Technical Bulletin 8. Geneva, Dec., 1908.

> The results from this cheese accord with the idea that aside from the lactic group there is no single group or at least no single species of bacteria absolutely essential to the ripening process.

The work of previous investigators has shown that the liquefying, the gas-forming, and the inert bacteria are not essential factors in the ripening of Cheddar cheese, since all or any one of these groups may be absent and yet the cheese may ripen in a normal manner. It is true that all of these groups are usually represented in Cheddar cheese, since they are present in milk, but the numbers are small, and in the case of the liquefying organisms there is no evidence that growth ever occurs during the ripening process.

Yeasts can not be classed as an important factor since they may be absent from a normal cheese.

The work of previous investigators may be summarized in the statement that the group of bacteria represented by *Bacterium lactis acidi* is the only one that up to the present has been shown to be of constant occurrence in Cheddar cheese. This fact together with the enormous numbers, amounting to millions and at times over a billion per gram of the fresh cheese, leaves no doubt of the importance of this group of organisms in Cheddar cheese, and undoubtedly in all cheese that undergoes a ripening process.

THE ROLE OF BACTERIUM LACTIS ACIDI IN CHEDDAR CHEESE.

The empirical methods of the Cheddar cheesemaker demand a milk so far advanced in the acid fermentation that during the few hours between time of curdling and placing the curd in the press acid development is rapid. The increasing acidity, as has long been known, favors the curdling of the milk by the rennet. Indeed the tests most frequently used in cheesemaking to determine the "ripeness" or acidity of the milk are those in which the time of curdling is noted, when a definite amount of rennet is added to milk at a definite temperature (tests of Monrad and Marschall). The Cheddar maker desires milk that has just passed through the "period of incubation." By this expression is meant the time during which no apparent increase in acidity results from the growth of acid-forming bacteria. This has been supposed to be due to the fact that no acid was formed by the rapidly growing organisms. More recently it has been pointed out by Rahn[1] that this is not the true explanation but that until the bacteria have increased to a great extent the amount of acid formed is so small as to escape detection. Whatever the explanation, it is true that the acid-forming bacteria may increase until there are millions per cubic centimeter and yet the acidity show no change whatever, as has been shown by Koning[1] and by Burri and Kürsteiner.[2]

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[1] Rahn, Otto. The fermenting capacity of the average individual cell (*Bacterium lactis acidi*). Science, new series, vol. 33, No. 849, pp. 539–540. New York, Apr. 7, 1911.

At last the acidity begins to develop with increasing rapidity until it reaches a point where it begins to exert an inhibitive effect upon the growth of the organism. In Table 1 are given some data illustrating the rate of acid development in milk kept at 95° F. It will be noted in both samples that the initial rate of increase in acid is small, that it reaches a maximum that may be over 0.15 per cent per hour and then declines. Both samples of milk were slightly too acid for cheesemaking.

TABLE 1.—*Rate of development of acid in milk kept at 95° F.*

	Hours.					
	0	1	2	3	5	24
Sample 1:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Acidity	0.24	0.30	0.40	0.47	0.71	1.00
Increase per hour	....	.06	.10	.07	.12	.015
Sample 2:						
Acidity	.20	.24	.34	.5	.74	.99
Increase per hour	....	.04	.10	.16	.12	.012

This rapid increase in acidity is the result of the growth of the acid-forming bacteria in the favorable environment. In Table 2 are given the results of the bacteriological examination of two samples of milk kept at 95° F. for a number of hours. It will be noted that the increase in numbers of bacteria, like that of the acidity, goes on with increasing rapidity until a maximum is reached, after which the growth is less and less rapid.

TABLE 2.—*Increase of bacteria per cubic centimeter in milk kept at 95° F.*

[Number of bacteria expressed in millions.]

	Hours.					
	0	2	4	6	8	10
Sample 1	59	83	231	927	1,064	1,167
Sample 2	4	....	157	826	1,545	1,982

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[1] Koning, C. J. Der Säuregrad der Milch. [Pharmaceutisch Weekblad, 1904] Milchwirtshaftliches Zentralblatt, vol. 1, No. 7, pp. 289–305, July; No. 8, pp. 337–356, August. Leipzig, 1905. See p. 294.

[2] Burri, R., and Kürsteiner, J. Untersuchungen über die Reifung der Käsereimilch. Landwirtschaftliches Jahrbuch der Schweiz, vol. 24, pp. 437–466. Bern, 1910.

It is essential that the acid development should be rapid during the time between the curdling of the milk and pressing the curd. The modern Cheddar maker insures this by the addition of large numbers of acid-forming bacteria in the form of a starter.

EFFECT OF CURDLING ON DISTRIBUTION OF BACTERIA IN MILK.

The solid bodies present in the milk will be held by the curd in the same manner as the formation of aluminum or ferric hydrate in water enmeshes the solid bodies present, or the coagulating of albumen in a solution removes turbidity therefrom, as in the clearing of bacteriological media and of wine.

In order to illustrate the effect of curdling on the distribution of bacteria several samples of milk were subjected to a quantitative examination. Rennet solution was then added and the curd cut. As soon as possible a sample of the whey was likewise examined. In Table 3 are given the data obtained from a number of such examinations. It will be noted that in all cases a unit volume of the whey contained less bacteria than the milk before curdling. From the average figures of the determinations approximately 77 per cent of the bacteria were retained in the curd in the trials made in the laboratory.

TABLE 3.—*Number of bacteria per cubic centimeter in milk and in whey immediately after curdling—Laboratory experiments.*

[Number of bacteria expressed in thousands.]

	Trial No.					
	1	2	3	4	5	6
Milk	128,000	11,000	2,050	155,000	23,000	59,000
Whey	34,000	2,900	730	756	773	776

A number of similar examinations were made under practical conditions in the cheese room, the sample of milk being taken from the cheese vat and the whey after cutting the curd in the usual manner. The data are given in Table 4. It will be noted that the results are similar to those obtained in the laboratory. Approximately 73 per cent of the bacteria in the milk were retained in the curd.

TABLE 4.—*Number of bacteria per cubic centimeter in milk and in whey immediately after curdling—Samples from the cheese vat.*

[Number of bacteria expressed in thousands.]

	Trial No.				
	1	2	3	4	5
Milk	5,600	6,400	5,430	4,000	6,500
Whey	3,000	1,290	2,400	210	460

The result of curdling and the shrinking of the curd is that the acid-forming bacteria of the milk are concentrated in the curd, which soon after cutting occupies but a fraction of the volume of the original milk. This concentration, together with the favorable environment, results in a rapid formation of acid in the curd.

This condition should result in a more rapid increase of acid in a whey in which the curd is allowed to remain than in a portion of the same whey removed from the curd. As the curd shrinks the expelled whey should bring with it a portion of the acid that has been formed in the curd; this, together with osmotic action, should increase the acidity of the whey in contact with the curd.

In order to demonstrate this a sample of milk was curdled, the curd cut, and as soon as possible a portion of the whey removed to a separate vessel. Acidity determinations were made at intervals. The results are given in Table 5. It will be noted that in every case the acidity of the whey in contact with the curd increased much more rapidly than that of the whey not in contact with the curd.

TABLE 5.—*Development of acid in whey alone and in whey in contact with curd.*

	Hours.						
	0	2	4	6	8	10	12
Sample 1:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Whey	0.09	0.09	0.10	0.13	0.16	0.24	0.36
Whey and curd	.09	.10	.16	.17	.32	.47	.54
Sample 2:							
Whey	.14	.20	.30	.35	.49	....	....
Whey and curd	.14	.27	.48	.53	.68	....	....
Sample 3:							
Whey	.10	.12	.12	.22	.33	....	....
Whey and curd	.10	.12	.16	.32	.49	....	....
Sample 4:							
Whey	.09	.10	.11	.13	.14	.33	....
Whey and curd	.09	.10	.13	.18	.20	.42	....

It was thought that if a sample of milk was curdled by rennet and the curd cut and allowed to settle to the bottom of a deep container, the whey at different levels should show varying degrees of acidity if the container were so protected that convection currents did not tend to mix the liquid. In other words, the acid whey expelled would tend to accumulate in the lower portion of the container.

In order to test this, deep beakers were filled with milk, the milk curdled with rennet, and the curd cut and allowed to settle. The beakers were kept in a thermostat at 95° F.; thus no convection currents were present, since care was taken to heat the milk to the same temperature before curdling. The samples of whey were removed in such a manner as not to mix the different layers. In Table 6 the results of a number of trials are given. It will be seen that the acidity of the bottom layers increases much faster than that of the upper layers, the difference being in some cases 0.4 per cent.

TABLE 6.—*Acidity of whey at the top and bottom of a vessel containing whey and curd.*

	Hours.						
	0	2	4	6	8	10	12
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sample 1:							
Top	0.09	0.09	0.11	0.12	0.16	0.27	0.40
Bottom	.09	.10	.13	.22	.49	.67	.68
Sample 2:							
Top	.14	.21	.32	.36	.56	....	....
Bottom	.14	.34	.64	.71	.80	....	....
Sample 3:							
Top	.08	.08	.09	.09	.12	.18	.24
Bottom	.08	.08	.09	.11	.15	.34	.45
Sample 4:							
Top	.09	.10	.13	.14	.17	.25	....
Bottom	.09	.10	.14	.22	.24	.59	....

It is thus shown in a number of ways that the location of acid development is in the curd rather than in the whey.

It has been shown that paracasein will absorb and probably combine with acids. If this is so, a portion of the acid formed in the curd should be retained in loose chemical combination and the acidity of a sample of milk should increase more rapidly than that of the whey from the same milk, even though the whey is in contact with the curd. The data given in Table 7 show this to be true. The figures represent the increase in acid at the end of each period over the initial acidity of the milk or whey and curd. This leaves no doubt that a portion of the acid is retained by the curd, and is proof of an earlier statement, that a cheese in which acid is developed during the process of making will have a different acidity from one with an equal content of moisture, but in which no acid is formed during the making.

TABLE 7.—*Increase in acidity of milk and of whey in contact with curd.*

	Hours.					
	2	4	6	8	10	12
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Sample 1:						
Milk	0.19	0.34	0.64	0.73	....	....
Whey and curd	.13	.32	.38	.52	....	....
Sample 2:						
Milk	.00	.01	.09	.32	0.55	0.74
Whey and curd	.00	.01	.02	.05	.18	.26
Sample 3:						
Milk	.04	.21	.44	.69	....	....
Whey and curd	.05	.11	.16	.28	....	....
Sample 4:						
Milk	.03	.15	.43	.63	....	....
Whey and curd	.03	.04	.16	.25	....	....

EFFECT OF ACID ON EXPULSION OF THE WHEY.

It has been shown by Sammis, Suzuki, and Laabs [1] that the expulsion of whey from the curd is directly proportional to the amount of acidity present; at least, in the case of percentages of acidity that are met with in normal cheese curds. The growth of lactic-acid bacteria in the curd and the consequent development of acidity are necessary to secure a curd with the proper moisture content.

EFFECT OF ACID ON THE TEXTURE OF THE CURD.

The curd from milk in which no growth of acid-forming bacteria has taken place shows but a slight tendency to mat or for the pieces of curd to fuse. If, however, acid is formed in the pieces of curd, they undergo such a change in texture that as soon as they are allowed to settle to the bottom of the vat they soon unite to form a single mass of curd. In the making of cheese by the Cheddar process it is essential that this matting take place.

The change in texture which the curd undergoes is due to the action of the acid on the paracasein, forming a substance that, when warmed, can be drawn into threads. The basis of the "hot iron" test as used to determine the time to draw the whey is the formation of this compound by the acid.

At the time the curd is placed in the press there are numerous spaces between the curd particles. It is essential that the curd be so plastic that, under the influence of the pressure, the particles undergo perfect fusion, so that the entire cheese is one mass, perfectly free from irregular-shaped mechanical holes. Such a fusion does not occur in the absence of acid formation in the curd.

THE RÔLE OF ACID IN THE RIPENING OF CHEESE.

In the ripening process proper the acid resulting from the fermentation of the sugar by the organisms of the *Bacterium lactis acidi* group has an important rôle. As has been shown by numerous investigators, the sugar in the cheese is all fermented within a few days. It was shown by Babcock and Russell,[2] also by Jensen,[3] and by Van Slyke, Harding, and Hart [4] that rennet extract not only has a curdling effect but has a digestive action in the presence of an activating acid such as is present in the cheese. The rapid proteolysis occurring during the first part of the ripening process is largely due to the action of the pepsin.

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[1] Sammis, J. L.; Suzuki, S. K., and Laabs, F. W. Factors controlling the moisture content of cheese curds. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 122. Washington, 1910.

[2] Babcock, S. M.; Russell, H. L.; and Vivian, A. Influence of rennet on cheese ripening. Wisconsin Agricultural Experiment Station, Seventeenth Annual Report, pp. 102–122. Madison, 1900.

[3] Jensen, Orla. Studien über die Enzyme im Käse. Landwirtschaftliches Jahrbuch der Schweiz, vol. 14, pp. 197–233. Berne, 1900.

[4] Van Slyke, L. L.; Harding, H. A.; and Hart, E. B. Rennet-enzyme as a factor in cheese ripening. New York Agricultural Experiment Station, Bulletin 233. Geneva, June, 1903.

Variations in the amount of rennet extract added to the milk result in differences in the rate of ripening, as has been shown by numerous investigators. This can be explained only through the variations in the pepsin content of the cheese. The action of rennet extract in the presence and absence of lactic organisms is demonstrated in Plate I, figure 1. A 4 per cent solution of agar was added to sterile milk in the proportion of 1 to 1. A portion of the milk agar was heavily inoculated with a lactic organism and the plates incubated for 24 hours; the other portion was not inoculated. At the end of the period of incubation strips of filter paper were moistened with rennet extract and placed on the plates, which were then incubated at 37° C. for one hour. The photograph was taken at the end of the period. It will be noted that in the presence of the lactic organisms the casein has been rendered soluble by the rennet extract, while in the absence of the organisms no such marked digestion has occurred. The digestion of the casein has resulted in the destruction of the opacity of the milk agar so that a number placed beneath the dish can be read, while in the case of the milk agar from which the lactic organisms were absent no trace of a similar number can be distinguished. In the milk agar conditions are very similar to those obtaining in cheese, the activating acid being of like origin.

It would thus seem that if a cheese was made from milk that contained but few acid-forming organisms the rate of ripening would be delayed. In order to test this hypothesis, a cheese was made from very clean milk, containing scarcely any acid-producing organisms, and no starter was added. No acid whatever was formed during the making process. The milk after standing 24 hours at 20° C. had an acidity of but 0.19 per cent. In order to insure proper curdling, the acidity of the milk was raised to 0.25 per cent by the addition of hydrochloric acid. In order to follow the rate of acid formation, determinations of the sugar present in the cheese were made at intervals. The results are given in Table 8.

TABLE 8.—*Sugar content of cheese made from milk containing few lactic bacteria.*

Time.	Sugar content.	Acidity.	Time.	Sugar content.	Acidity.
Days.	*Per cent.*	*Per cent.*	*Days.*	*Per cent.*	*Per cent.*
1	1.51	.25	8	1.45	.27
2	1.49	.27	22	.94	.45
4	1.48	.27	46	.00	1.13

The sugar disappears from a normal cheese in 3 to 5 days, while on the twenty-second day over one-half of the sugar remained in the experimental cheese. The maximum bacterial content, as measured by the ordinary plate cultures, was not attained until after the sixth week. The rate of ripening, as measured by the change in texture and development of flavor, was correspondingly slow. At three months the cheese still showed a spongy texture and scarcely any cheese flavor.

THE PROTECTIVE ACTION OF ACID.

The putrefactive bacteria of the groups that are constantly present in milk, and hence in cheese, are unable to grow on account of the acid reaction which is maintained during the entire period of ripening. This protective action of acid was first demonstrated at the Wisconsin Experiment Station by Babcock and Russell,[1] who removed the sugar from curd by washing in water. The cheese developed most undesirable odors and tastes, and bacteriological examinations showed liquefying bacteria to be numerous. If lactose, glucose, or cane sugar were added to the washed curd, the ripening process was much more nearly normal because the acid reaction was thereby restored, due to the fermentation of the added sugar, and the putrefactive organisms were inhibited as in a normal cheese. In the experimental work on flavor development in Cheddar cheese, a number of cheeses were prepared from curd from which the sugar was removed by washing. In Plate I, figure 2, a normal and a washed-curd cheese are illustrated. The washed-curd cheese was devoid of texture, being a soft, plastic mass and having no resemblance to cheese in odor and taste. On the right of the picture is a cheese made from the same washed curd to which acid had been added, with the result that the firmness was restored.

The rôle of organisms of the *Bacterium lactis acidi* group in Cheddar cheese may be summarized as follows:

1. They favor the curdling process.
2. They favor the expulsion of the whey.
3. They permit of the fusing of the curd particles.
4. They activate the pepsin of the rennet extract.
5. They have a protective action against the putrefactive bacteria.

It is certain that this group is an essential factor in the ripening of Cheddar cheese. Their period of growth has been believed to be short, since it has not been supposed they can continue to develop after the disappearance of the sugar. It has been shown by numer-

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[1] Babcock, S. M., Russell, H. L., Vivian, A., and Hastings, E. G. Influence of sugar on the nature of the fermentations occurring in milk and cheese. Wisconsin Agricultural Experiment Station, Eighteenth Annual Report, pp. 162–176. Madison, 1901.

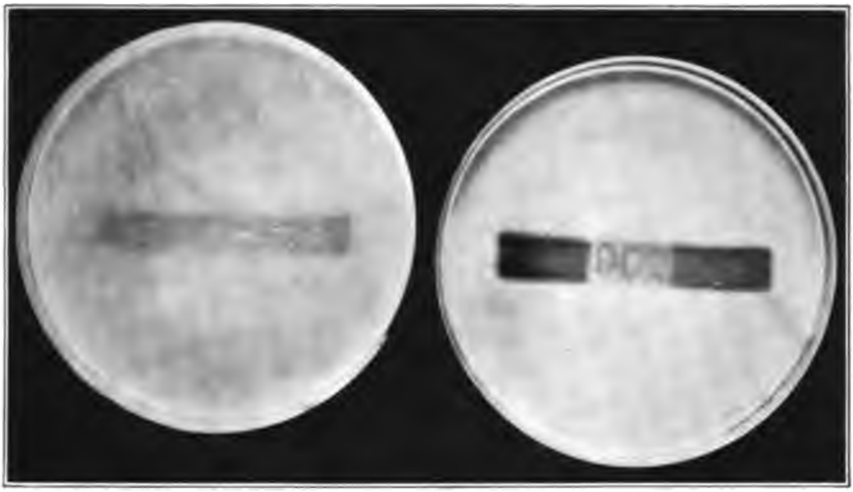

FIG. 1.—THE ACTION OF RENNET EXTRACT ON CASEIN SUSPENDED IN AGAR IN THE PRESENCE AND IN THE ABSENCE OF ACID-FORMING BACTERIA.

The same number (902) was placed beneath both plates at the time the photograph was taken. The digestion of the casein in the presence of the acid-forming bacteria has rendered the medium transparent and the number apparent, while in the absence of the acid-forming bacteria the digestive action has been almost nil.

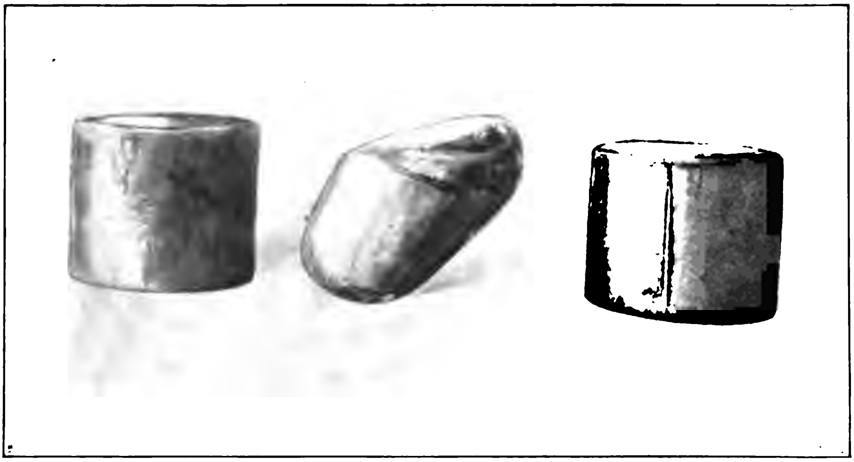

FIG. 2.—THE EFFECT OF ACID ON CHEESE.

On the left is a cheese made from normal milk by the usual process; in the center a cheese made from the same milk, the curd being washed free of sugar; on the right a cheese made from the same washed curd, to which acid had been added. The washed-curd cheese had no body and was a soft, plastic mass. The addition of acid restored the firmness of the body.

ous investigators that the period of maximum numbers is when the cheese is a few days old; that thereafter the decline in numbers is more or less rapid. In some cheeses, as will be shown later, high numbers may persist for long periods of time. It is not usually believed that they can exert any marked action in other lines than those that have been mentioned after growth ceases, although such a belief may not be well founded. Indeed, some facts would indicate otherwise.

The ripening process, both in regard to proteolysis and development of flavor, continues long after what is supposed to be the period of bacterial activity. A large amount of data is available as to the proteolytic changes going on in the ripening cheese, but until recently no data have been available to show that the compounds containing no nitrogen were likewise constantly changing. The content of the cheese in volatile fatty acids is constantly changing, and especially the relative amounts of the different acids. To explain these changes recourse must be had to enzyms, and most probably to those elaborated by the lactic organisms or to other types of bacteria that develop subsequently to what has been called the period of bacterial activity.

The data to be presented will show that the period of activity is not to be measured by determining the ordinary types of bacteria. The demonstration of continued bacterial growth does not, of course, eliminate the action of enzyms formed by the *Bacterium lactic acidi* group of organisms that during the early life of the cheese make up most of the flora.

THE RATE OF BACTERIAL GROWTH IN CHEESE.

In the course of the cooperative work carried on by the Dairy Division of the Department of Agriculture and the Wisconsin Experiment Station a large number of cheeses have been examined bacteriologically. Some were examined at frequent intervals during the making process and during the first portion of the ripening period; others were examined at less frequent intervals during the entire period of ripening.

METHODS OF EXAMINATION.

The method of examination used was the grinding with sterile quartz sand of a sample of the cheese taken from various parts of a plug and handled under aseptic conditions. Inoculations in varying dilutions were made from the cheese suspension into lactose-agar plates. At first the period of incubation of the plates was 48 hours at 37° C. Later the incubation at 37° was supplemented by a further incubation at 20°. This method of incubation allows the development of the maximum number of organisms and insures the growth of the colonies to a maximum size, an important point when it is desired to differentiate the various types present. Gelatin containing no added sugar was used in a portion of the work; the plate cultures were then incubated at 18° to 22° C. for 10 days and for even longer periods when slightly lower temperatures were employed.

RESULTS OF THE WORK.

The data collected by means of the methods that have been used by other investigators of Cheddar cheese serve simply to confirm their work and to emphasize the number of organisms of the *Bacterium lactis acidi* group that are to be found during the early part of the ripening period. A portion of the data is presented in Tables 9, 10, and 11 because it gives a very complete picture of the bacterial development during and subsequent to the making of the cheese.

The maximum number of bacteria as measured by the lactose-agar plate cultures occurs early in the ripening process. In 8 of the 11 cheeses examined, as shown in Tables 9 and 10, the greatest number of bacteria was found within 48 hours. In the case of the examinations detailed in Table 11, it will be noted that the maximum numbers of bacteria as determined by lactose-agar plates have been found much later, namely, at the end of the fourteenth, forty-fifth, and seventy-seventh days. Thus, in no case was the maximum number found at the first determination. It is not believed, however, that these cheeses, selected especially to illustrate certain points to be discussed later, give a true picture of the initial development of bacteria. In the case of 9 of the 13 to be mentioned later, the maximum number of bacteria was found on the first, second, or third examinations. Harding and Prucha[1] obtained similar results. Seven out of 9 cheeses examined showed the maximum number of bacteria at the first examination, 1 at the second, and 1 at the fourth.

It is impossible to determine the time at which the growth of any particular type of organism in cheese ceases. As the fermentation in the cheese progresses and the accumulation of by-products increases, cell death begins to occur. As long as the process of cell division is more rapid than death of the cells, an increase in living bacteria will be shown by the plate cultures. Soon death of the cells is more rapid than cell division. At this point the decrease in apparent numbers begins, although growth may continue for a much longer period. It seems probable that the growth of the bacteria of the *Bacterium lactis acidi* group continues until the sugar is completely fermented. In milk the cessation of growth is due to the appearance of free acid, in cheese to the disappearance of an essential food, a fermentable carbohydrate.

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[1] Harding, H. A., and Prucha, M. J. The bacterial flora of Cheddar cheese. New York Agricultural Experiment Station, Technical Bulletin 8. Geneva, Dec., 1908.

The large numbers of bacteria found during the first days are striking; the number as given in the tables is far below the actual number, due to the impossibility of breaking up the colonies in the tough cheese. It is probable that the germ content of cheese often amounts to hundreds of billions of living bacteria in each gram of the moist cheese. From what is known of the number of cells in a gram of moist bacterial growth, it is certain that at the time the maximum numbers of the organisms of the *Bacterium lactis acidi* group are found, at least 0.1 per cent of the moist cheese consists of bacteria.

TABLE 9.—*Numbers of bacteria per gram in Cheddar cheese as determined by lactose-agar plate cultures.*

[Numbers expressed in millions.]

Cheese No.	Days.										
	0	1	2	3	4	5	6	7	9	10	12
434	31	....	....	490	....	537	489	21	......	43	......
438	4.5	....	174	......	134	292	3	......	......	1	......
442	1.3	971	831	133	....	......	......	221	......	......	......
474	58	1,657	987	......	325	......	407	......	239	......	141
475	158	1,638	1,344	987	....	......	545	......	69	......	736
476	138	1,311	2,518	......	616	......	195	......	293	......	728
477	53	1,925	2,171	......	1,916	......	221	......	65	......	598

TABLE 10.—*Numbers of bacteria per gram in Cheddar cheese as determined by lactose-agar plate cultures.*

[Numbers expressed in millions.]

Cheese No.	Milk.	Curd at salting time.	12 hours.	Days.										
				1	2	4	6	14	21	28	35	49	70	98
580	8	160	332	586	235	145	165	51	284	285	104	132	128	114
581	0.5	326	1,048	736	405	684	184	211	290	453	261	228	291	212
582	.7	912	623	709	848	522	853	369	348	314	326	436	193	45
583	.5	839	965	569	580	1,025	184	401	319	144	504	661	168	55

TABLE 11.—*Numbers of bacteria per gram in Cheddar cheese as determined by plate cultures.*

[Numbers expressed in millions.]

Number of days.	Cheese No. 1.		Cheese No. 54.		Cheese No. 91.		Cheese No. 92.	
	Lactose-agar culture.	Gelatin culture.	Lactose-agar culture.	Gelatin culture.	Lactose-agar culture.	Gelatin culture.	Lactose-agar culture.	Gelatin culture.
2					150		250	150
4	3							
8					61	120	400	340
11	8	14						
14			32		1,400	530	500	
22	2.5	10			58	1,600	35	
30	2	10	15	70				
37					270	480		100
45	40	25			1,400		340	
56			32	51	1,300	250	225	225
77			51	40				
86	36.5	24			128	320	250	84
100			8.5	12	74	65	100	120
113	5	5			145	142	132	87
124			14	12	50	28.5	145	96
143	13	13	22.5	12.5	18	23.5	38.5	38
155					15	10.5		32
165					17.5	5.5	63	
176	3.5	2.5					9	5.5
187			6		7.5		12.5	2

According to the determinations of MacNeal, Latzer, and Kerr,[1] there are about 5,300 billion colon bacilli in a gram of dry growth. Figuring on a moisture content of 90 per cent, there would be 530 billion in a gram of the moist growth. From determinations made by weighing out 1 gram of the moist growth of a coccus form from cheese, making a uniform suspension of this in a known volume of water, and taking an equal volume of this suspension and of normal blood and counting the number of bacteria and red corpuscles we have obtained an average figure of 1,150 billion cells per gram of the moist growth. The basis for this method of counting is the fact that from a known number of red blood cells one can figure the volume used, since the red cells are practically a constant quantity. The average volume of the colon organism is 1.13 cubic microns; of the coccus 0.5236. The agreement in the determinations is thus very close.

It is not to be supposed that, so far as the number of bacteria is concerned, all cheese will be similar. The results shown in Table 11 emphasize this point; two of the cheeses, Nos. 1 and 54, showed at no time over a few million bacteria per gram, while the remaining two had a consistently high germ content. Such differences may be due to many causes. The period of maximum numbers is followed by a decline, rapid in some instances, slow in others. At the time the cheese is fully ripe millions of living lactic bacteria are usually present in each gram of cheese. Living lactic organisms have been found by one of the authors in a cheese over 4 years old.

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[1] MacNeal, Ward J.; Latzer, Lenore L.; and Kerr, Josephine E. The fecal bacteria of healthy men. Journal of Infectious Diseases, vol. 6, No. 2, pp. 123–169, Apr. 1; No. 5, pp. 571–609, Nov. 26. Chicago, 1909.

The ripening of the cheese, both in reference to proteolysis and flavor development, continues long after this group of organisms has ceased to grow. A large amount of data is available to show that a constant change in the nitrogenous bodies present is taking place. It has also been shown by the authors that the content of the cheese in fixed and volatile acids changes during the ripening process. To explain these latter changes, recourse must be had to enzyms elaborated by the lactic bacteria, or else it must be supposed that other groups of organisms develop subsequently.

THE ENZYMIC ACTION OF LACTIC BACTERIA.

The work of Buchner, Herzog, and others has shown the presence of an enzym in certain lactic-acid-producing bacteria that are essentially different from those predominating in cheese. This intracellular enzym, which can be demonstrated only after the disintegration of the cell, forms small quantities of lactic acid from sugar. So far as is known to us, a similar enzym has never been demonstrated in organisms of the *Bacterium lactis acidi* group. The growth of these organisms on all media is so meager that it is very difficult to obtain a sufficient amount of the growth so that it can be treated by methods similar to those employed by Buchner and others. An acid-producing enzym in the lactic bacteria has, however, been demonstrated by quite different methods. It had been noted that when a sample of raw or sterilized milk in which varying numbers of lactic bacteria had been allowed to develop, and to which a preservative, as chloroform or toluol, had been added, the cells soon disappeared, or at least could no longer be detected by microscopical examination. It was thought that if the cells would undergo disintegration after having been killed by an antiseptic while in an actively growing condition, any enzyms present should exert their peculiar action as well as though the cells were mechanically ruptured.

The following experiment was planned: Bottles of fresh raw milk and of the same milk heated to 97° C. for a short time were inoculated with a pure culture of *Bacterium lactis acidi.* At varying periods in the development of acid a portion of the milk was removed and preserved with 3 per cent of toluol. In the bottles treated soon after inoculation a small number of bacteria were present, while in those to which the preservative was added at a later stage in the development of acid a much larger amount of bacterial growth was present. If any enzymic action occurred, the bottles should show a quantitative difference in the amount of acid formed corresponding to the amount of bacterial cells present. Raw milk, when preserved with chloroform or toluol, gradually increases in acidity. This increase occurs when the milk contains only the bacteria that come from the interior of the udder and to which the preservative has been added as soon as drawn. In a bottle of milk put up in 1898 by Dr. S. M. Babcock and preserved with an excess of chloroform an acidity of 0.7 per cent was found in 1910, while the sugar content was as great as in the fresh milk, being 5 per cent. This increase of acid has been shown in all samples of milk preserved by the authors. It is undoubtedly due to the formation of amino acids by the inherent proteolytic enzyms of the milk.

In the bottles of raw milk in the experiment two acid-forming factors might be present: First, one forming an acid from the protein; second, the enzym of the lactic bacteria acting on the sugar. In the bottles of heated milk only the latter could be active, since the degree of heat was sufficient to destroy all the inherent enzyms of the milk. The milks thus differently treated should show a quantitative difference in increase in acid if the bacterial enzyms were capable of such action. The first bottle of the raw-milk series contained a minimum number of bacteria, since the milk was but a few hours old and drawn under clean conditions. The acidity in this bottle was that of the fresh milk. Three per cent of a pure lactic organism in milk was then added to the remainder of the raw milk. The second bottle was filled immediately after the addition of the culture. The milk was then incubated and at varying intervals bottles were filled and toluol added. The first acid determinations were made at once after adding the toluol to each bottle. It will be noted in Table 13 that the acidity in the case of the raw milk varied from 0.184 to 0.408 per cent. The increasing acidity indicated a great increase in the numbers of bacteria, which was also shown by microscopical preparations made from each bottle at the time the preservative was added.

The set of bottles filled with heated milk were treated in the same manner as the raw milk. The first bottle of this set contained practically no living bacteria. The acidity in the case of the remainder ranged from 0.203 to 0.456 per cent.

In order to determine how long the cells persisted in an active condition, tubes of milk were heavily inoculated from the various bottles. The results are given in Table 12.

TABLE 12.—*Results of inoculations of sterile milk from the bottles of milk containing 3 per cent toluol.*

Bottle No.	Tube.	Growth from inoculations made after—		
		1 day.	3 days.	5 days.
1......	1	–	–	....
	2	–	–	....
2......	1	–	–	....
	2	–	–	....
3......	1	–	–	....
	2	–	–	....
4......	1	–	–	....
	2	–	–	....
5......	1	–	–	....
	2	–	–	....
6......	1	–	–	....
	2	–	–	....
7......	1	+	–	....
	2	–	–	....
8......	1	–	–	–
	2	–	–	–
9......	1	+	+	–
	2	–	+	–
10......	1	–	–	–
	2	–	–	–
11......	1	–	–	–
	2	–	–	–
12......	1	+	–	–
	2	+	–	–
13......	1	+	–	–
	2	+	–	–
14......	1	–	+	–
	2	–	–	–

The results of the inoculation of sterile milk show that no growth could have taken place in the bottles after the addition of the toluol, and that within a short time the lactic organisms were all destroyed. Any acid formed in the raw milk after the fifth day must have been due in part, at least, to the inherent proteolytic enzyms of the milk; any increase of acid in the heated milk must have been due to the enzyms set free by the disintegrating cells.

Microscopical preparations were made at intervals from the various bottles. The smears were stained with a saturated aqueous solution of methylene blue. With this stain the cells can be distinguished for some time after they can no longer be demonstrated by the Gram-Weigert stain, which has been used in the examination of smears direct from cheese (See p. 32.) In raw milk the cells were agglutinated into large clumps. The number in the preparations made at various intervals became less and less, and after 45 days they had completely disappeared. As the cells deteriorated they stained more and more faintly.

In the heated milk the disappearance of the cells was less rapid. After 74 days some could be distinguished, although their outlines seemed to be more or less distorted.

In the bottles the following conditions were present: The mass of cells varied widely; cell growth undoubtedly ceased as soon as the antiseptic was added and within a few hours the cells were all destroyed, having been killed while in an active condition by an agent that is supposed to have the minimum effect on the intracellular enzyms. The cells disintegrated more or less rapidly. It would seem that if any acid-forming enzyms were present in the bacterial cells they should manifest themselves under these conditions by the formation of acid. Acid determinations were made with the greatest precautions possible under the conditions of the experiment. The results are given in detail in Table 13:

TABLE 13.—*Increase of acidity in milk preserved with 3 per cent toluol.*

RAW MILK.

Sample.	When preservative was added.	Days.						
		1	13	28	59	90	121	150
Bottle No. 1:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Acidity	0.184	0.19	0.234	0.273	0.29	0.317	0.368	0.368
Increase		.006	.05	.089	.106	.133	.184	.184
Bottle No. 2:								
Acidity	.204	.22	.257	.299	.326	.349	.414	.414
Increase		.016	.053	.095	.122	.145	.21	.21
Bottle No. 3:								
Acidity	.223	.261	.308	.377	.359	.4	.515	.506
Increase		.038	.085	.154	.136	.177	.292	.283
Bottle No. 4:								
Acidity	.266	.261	.326	.345	.391	.414	.492	.494
Increase		−.005	.06	.079	.126	.148	.226	.228
Bottle No. 5:								
Acidity	.282	.332	.404	.45	.492	.423	.644	.584
Increase		.05	.122	.168	.21	.141	.362	.302
Bottle No. 6:								
Acidity	.327	.356	.408	.443	.515	.538	.644	.676
Increase		.029	.081	.116	.188	.211	.317	.349
Bottle No. 7:								
Acidity	.408	.489	.561	.579	.616	.63	.745	.823
Increase		.081	.153	.171	.208	.222	.337	.415
HEATED MILK.								
Bottle No. 8:								
Acidity	0.184	0.18	0.175	0.197	0.212	0.243	0.262	0.267
Increase		−.004	−.009	.013	.028	.059	.078	.083
Bottle No. 9:								
Acidity	.203	.206	.202	.225	.258	.27	.276	.276
Increase		.003	−.001	.022	.055	.067	.073	.073
Bottle No. 10:								
Acidity	.256	.285	.317	.331	.338	.354	.363	.372
Increase		.029	.061	.075	.082	.098	.107	.116
Bottle No. 11:								
Acidity	.308	.356	.368	.395	.394	.423	.432	.451
Increase		.048	.06	.087	.086	.115	.124	.143
Bottle No. 12:								
Acidity	.349	.427	.423	.46	.428	.492	.54	.543
Increase		.078	.074	.111	.079	.143	.191	.194
Bottle No. 13:								
Acidity	.41	.46	.45	.46	.497	.515	.561	.672
Increase		.005	.04	.05	.087	.105	.151	.262
Bottle No. 14:								
Acidity	.456	.494	.519	.552	.528	.599	.68	.708
Increase		.038	.063	.096	.072	.143	.224	.252

From the conditions of the experiment it is to be expected that the increase of acidity in the raw milk would be greater than in the heated milk, and that if the bacterial enzyms were operative the increase in acid would be directly proportional to the amount of enzym present or to the mass of cells. It will be noted that these are the conditions shown to be present by the figures given in the table. The data from three bottles of each of the raw and heated milks are given in graphical form in figures 1 and 2. The bottles

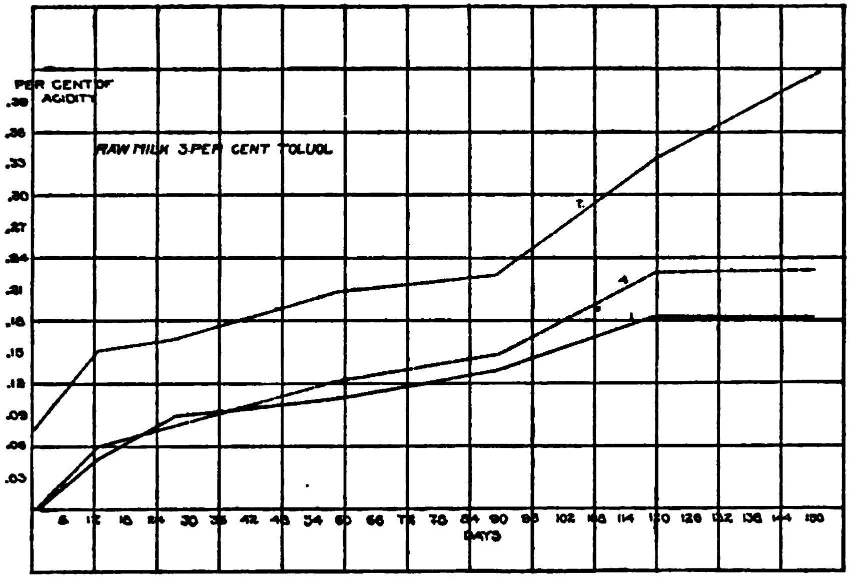

FIG. 1.—Increase of acidity in raw milk preserved with 3 per cent toluol. Bottle 1 contained the minimum number of bacteria, bottle 7 the maximum, and bottle 4 an intermediate number.

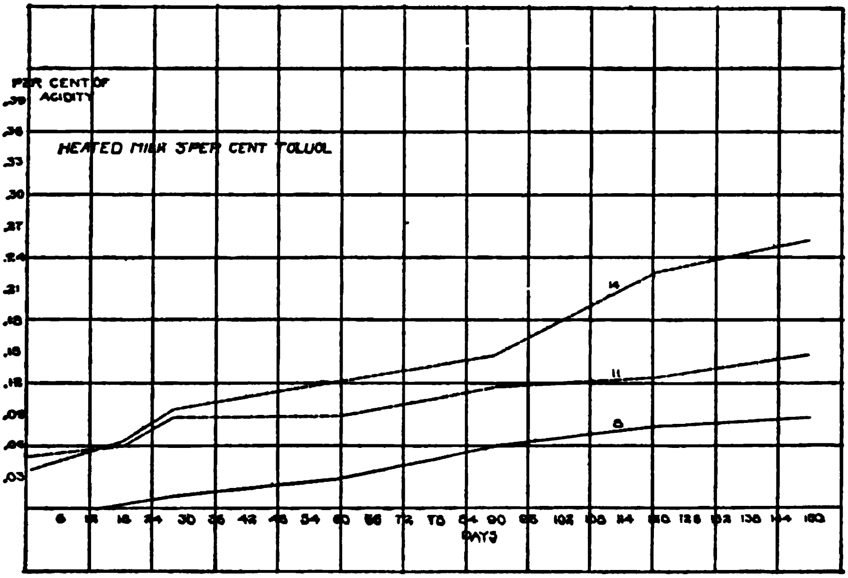

FIG. 2.—The increase of acidity in heated milk preserved with 3 per cent toluol. Bottle 8 contained the minimum number of bacteria, bottle 14 the maximum, and bottle 11 an intermediate number.

selected were the ones containing the minimum and maximum numbers of bacteria and an intermediate bottle from each set. The curves presented show the results to be entirely consistent with what might be expected.

In order to make the comparisons more easy there are given in Table 14 the rate of daily increase for each bottle of the two sets. The difference between the increase of acid in the raw milk and the heated milk should give the increase in the raw milk due to the inherent enzyms of the milk. This increase should be constant, or nearly so, since the same amount of enzym was operative in each bottle, although under somewhat different conditions, as regards acidity in the different bottles.

TABLE 14.—*Daily increase in acidity in bottles of raw and heated milk preserved with toluol.*

Raw milk.		Heated milk.		Increase (due to enzyms of milk).
	Per cent.		*Per cent.*	*Per cent.*
Bottle 1	0.0012	Bottle 8	0.0005	0.0007
Bottle 2	.0014	Bottle 9	.0005	.0009
Bottle 3	.0018	Bottle 10	.0007	.0011
Bottle 4	.0015	Bottle 11	.0010	.0005
Bottle 5	.0020	Bottle 12	.0013	.0000
Bottle 6	.0023	Bottle 13	.0017	.0007
Bottle 7	.0027	Bottle 14	.0017	.0016

It will be noted that the daily increase is proportional to the amount of bacteria present, and that the daily increase due to the inherent enzyms of milk is as constant as could be expected. The comparison has been made bottle for bottle in the two series. This introduces an error, since the amount of bacterial cells present in the compared bottles of raw and heated milk was not always the same. In the case of bottles 2 and 9, which are compared, the initial acidity was identical, while in the case of bottles 6 and 13, which are also compared, the initial difference in acidity was 0.083 per cent. The results seem to leave no doubt concerning the presence of an acid-forming enzym in the organisms of the *Bacterium lactis acidi* group that acts on the milk sugar. It might be thought that the increase in acidity was due to the production of amino acids by a proteolytic enzym. In this case the soluble nitrogen must be augmented. That this does not occur has been shown by numerous investigators.

The experiment was repeated in full detail with identical results. The increase in acid can not be asserted to be due to the formation of lactic acid, since, of course, no qualitative tests could be made in the presence of the lactic acid present in the milk at the beginning of the experiment.

It is true that in cheese the sugar disappears within a few days, and the enzym which was active under the conditions of the experiment could therefore not be active in cheese. This group of organisms has been believed to be peculiarly deficient in enzyms. It has even been claimed that they were the only bacteria devoid of catalase; no proteolytic enzyms have been demonstrated in them, and heretofore none acting on carbohydrates with the formation of acid. It is very probable that various classes of enzyms are formed by the lactic bacteria. As has been shown, a considerable part of the mass of the cheese consists of the cells of these organisms, which slowly disintegrate and their intracellular products are set free. It is not at all improbable that these products are the casual agents of changes that occur in the cheese, and that the rôles of the lactic bacteria are not limited to those previously mentioned.

OTHER GROUPS OF BACTERIA IN CHEDDAR CHEESE.

It is difficult to conceive that the varied chemical changes that occur during the ripening of Cheddar cheese can be due directly or indirectly to the lactic bacteria alone. It seems as though other biological factors must be operative, but, as was previously stated, no one has demonstrated the constant occurrence in large numbers of any other group of bacteria than the lactic group in Cheddar cheese. With the purpose of making a more complete examination of the cheese during the entire ripening period, the plate-culture work has been supplemented by other methods.

DETERMINATIONS BY MILK-DILUTION AND PLATE-CULTURE METHODS.

Since no solid medium seemed to promise better results than the standard media hitherto employed, milk was chosen as the medium most likely to permit of the growth of other groups of bacteria possibly present. In a previous publication[1] data concerning the distribution of a group of rod-shaped lactic bacteria in milk and other dairy products have been given. Among these organisms are included those found in many fermented milks, the *Bacillus bulgaricus* group, also the *B. casei* group, to which the work of Von Freudenreich and Jensen has attracted attention, as well as many of the acidophilous organisms found especially in the alimentary tracts of animals. These organisms were found to be constantly present in milk, butter, and in all the samples of Cheddar cheese examined. No quantitative analyses of cheese were made, however, in the work to which reference has been made.

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[1] Hastings, E. G.; Hammer, B. W.; and Hoffman, C. Studies on the bacterial and leucocyte content of milk. Wisconsin Agricultural Experiment Station, Research Bulletin 6. Madison. June, 1909.

Von Freudenreich's work showed the constant presence in large numbers of the lactic bacilli in Emmental cheese. In the making of this cheese they are added to the milk in great numbers in the natural whey rennet employed, and the high temperature of the curd during the pressing of the cheese favors their development. These organisms find a more favorable condition for growth in milk than in any of the usual media, indeed some of the members of the group can not be cultivated except in milk.

With the idea of determining the number of the organisms of this group in cheese, inoculations in varying dilutions were made from cheese emulsions into flasks of sterile milk, which were protected from evaporation by tin-foil caps and incubated at 37° C. The dilutions increased by a ratio of 10, thus flasks of milk in the case of a single cheese might be inoculated with amounts of a cheese emulsion representing 0.001, 0.0001, and 0.00001 gram. The extent to which the dilutions were carried depended on the age of the cheese. An attempt was constantly made to carry the dilutions to a point where some of the flasks would remain sterile. The method is thus a quantitative one for bacteria that will grow under the conditions obtaining. The dilution method is to be considered a rough way of determining the number of certain classes of bacteria.

After incubation for one month at 37° C., the acidity of each flask was determined. The *Bacterium lactis acidi* group of organisms produce in average milk an acidity ranging from 0.7 to 1.25 per cent. The lactic bacilli produce an acidity usually exceeding 1.25 per cent. It has been the practice to infer that every flask of milk showing an acidity above 1.25 per cent after one month's incubation contains the lactic bacilli, either in pure culture or mixed with organisms of the *Bacterium lactis acidi* group. In the flasks showing an acidity less than 1.25 per cent it can not be inferred that the lactic bacilli are absent, since some cultures are found that produce no more acid than *Bacterium lactis acidi.* Many microscopical examinations were made of the flasks to establish the accuracy of the conclusions drawn from the data obtained by titrations. Microscopic examinations were also made of all the flasks from which the titrations did not give conclusive evidence concerning the organisms present. The smears were stained with Gram's stain and decolorized with a mixture of one part of anilin oil and two parts of xylol. This method of decolorizing removes the stain from the casein, but not from any of the organisms that have been found in cheese.

The dilution method thus gives information concerning the absolute and relative number of acid-forming bacteria of these two groups. It may also give information concerning the presence of still other types of bacteria when they are present in greater numbers than those of the groups already referred to, since they will then appear in the flasks in pure culture.

In Table 15 are given the results of the analysis of four cheeses. A portion of the data has been presented in Table 2 and is here repeated for ease of comparing the numbers of bacteria as determined by plate-culture methods and by the dilution method. It will be noted that the dilution method, as a rule, gives higher results than the plate culture. Out of 49 determinations, the dilution method gave higher results than the lactose-agar plate determinations in 30 cases. It is probable that the dilution method always gives higher results. If the results show a growth in a dilution of 1 to 10 millions, while the dilution of 1 to 100 millions gives a negative result, it can only be asserted that the bacterial content of the cheese was between 10 and 100 millions. It will be noted that the dilution method often shows many fold more bacteria than the plate cultures, and that the reverse is not often true. In cases where the latter gives the higher number, the excess is not great, only three or four times greater. The only explanation that can be given of the higher numbers obtained by the dilution method is that some types of bacteria present in the cheese that do not appear on the plate cultures find conditions favorable for growth in the milk. The results obtained by the dilution method indicate that other organisms than the *Bacterium lactis acidi* group are present in the cheese, undoubtedly in great numbers.

TABLE 15.—*Number of bacteria per gram of cheese as determined on lactose agar and gelatin plates, and in flasks of milk inoculated with high dilutions of cheese.*

[Numbers expressed in millions.]

Age.	Cheese No. 1.			Cheese No. 54.			Cheese No. 91.			Cheese No. 92.		
	Lactose agar.	Gelatin.	Milk dilution.	Lactose agar.	Gelatin.	Milk dilution.	Lactose agar.	Gelatin.	Milk dilution.	Lactose agar.	Gelatin.	Milk dilution.
Days. 2	......	......	......	......	......	......	150	......	1,000	250	150	100
4	3	......	10	......	......	......	......	......	10,000	......	......	1,000
8	......	......	......	......	......	......	61	120	1,000	400	340	100
11	8	14	10	......	......	......	......	......	100	......	......	100
14	......	......	......	32	......	1,000	1,400	530	10,000	500	......	1,000
22	2.5	10	1,000	......	......	......	58	1,600	1,000	35	......	10,000
30	2	10	1,000	15	70	10	......	......	......	......	......	......
37	......	......	......	32	......	100	270	480	1,000	......	......	1,000
45	40	25	10	......	......	......	1,400	......	100	340	100	1,000
56	......	......	......	32	51	10	1,300	250	100	225	225	10
77	......	......	......	51	40	1,000	......	......	......	......	......	......
86	36.5	24	10	......	......	......	128	320	100	250	84	100
100	......	......	......	8.5	12	10	74	65	100	100	120	1,000
113	5	5	10	......	......	......	145	142	100	132	87	1,000
124	......	......	......	14	12	10	50	28.5	100	145	96	100
143	13	13	10	22.5	12.5	100	18	23.5	100	38.5	38	10
155	......	......	......	......	......	......	15	10.5	10	63	32	100
165	......	......	......	......	......	......	17.5	5.5	100	9	5.5	10
176	3.5	2.5	1	......	......	......	......	......	......	......	......	......
187	......	......	......	6	......	1	7.5	......	10	12.5	2	100
208	2	1.5	10	1	......	100	......	......	......	......	......	......

From the results obtained from the determinations of the degree of acidity attained by the flasks of milk inoculated with varying amounts of cheese emulsion, and from the microscopic examinations of the same flasks, it has been possible to determine the relations existing between the different groups of acid-forming organisms, as well as their absolute numbers.

Table 16 has been constructed from such data. For ease in comparison the same data are expressed in Table 17 in percentages, and two additional cheeses are also included in the latter table. It will be noted from the data presented in Table 17 that during the early part of the ripening period the organisms of the *Bacterium lactis acidi* group make up over 90 per cent, and in many cases approximately 100 per cent, of the acid-producing flora of the cheese. With increasing age the ratio changes, until late in the ripening period the rod-shaped lactic bacilli predominate, and in many cases make up over 90 per cent of the acid-forming bacteria found in the cheese.

It will also be noted from the data given in Table 15 that the period at which the maximum number of bacteria is found, as determined by the dilution method in milk, is coincident with the appearance of the lactic bacilli, as shown in Table 16. Using any culture medium that furnishes favorable conditions for the growth of both groups of lactic bacteria, the maximum number of organisms should be found at the time when the group first to appear—the *Bacterium lactis acidi* group—has attained its maximum development, but before any considerable number of the cells have died, and at the time when the second group of organisms finds favorable conditions for growth in the cheese.

TABLE 16.—*Numbers of Bacterium lactis acidi and of acid-producing bacilli in cheese as determined in milk cultures.*

[Numbers expressed in millions.]

Age.	Cheese No. 1.		Cheese No. 54.		Cheese No. 85.		Cheese No. 91.		Cheese No. 96.	
	Bact. lactis acidi.	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.
Days.										
2	....	....	....	....	....	....	1,000	....	1,000	....
4	10	1	....	....	1,000	....	10,000	10	100	....
8	....	....	....	....	....	....	1,000	100	1,000	....
11	10	1	....	....	1,000	10	100	....	100	....
14	....	....	1,000	10	1	10	10,000	1	10,000	1
22	1,000	1,000	....	....	....	....	1,000	100	1,000	1
30	100	100	10	....	10	10	....	....	....	....
37	....	....	10	10	100	1	1,000	100	100	10
45	10	10	....	....	10	100	100	100	1,000	1
56	....	....	10	1	1,000	10	100	100	100	10
77	....	....	100	1	100	1	....	....	100	1
86	1	10	....	....	....	10	100	100	100	10
100	....	....	10	1	10	10	100	100	100	10
113	....	1	....	....	10	10	100	10	100	10
124	....	....	10	1	10	10	100	10	100	1
143	10	10	100	10	....	10	100	10	100	1
155	....	....	....	....	10	1,000	10	10	10	10
165	....	....	....	1	....	....	100	100	....	10
176	1	1	....	....	1	100	....	....	....	....
187	....	....	1	1	10	10	....	10	....	10
208	....	10	....	100	....	....	....	....	....	....

TABLE 17.—*Relative proportion of the Bacterium lactis acidi type and the lactic acid-producing bacilli, as determined by dilution cultures in milk.*

Age.	Cheese No. 1.		Cheese No. 54.		Cheese No. 58.		Cheese No. 85.		Cheese No. 91.		Cheese No. 92.		Cheese No. 96.	
	Bact. lactis acidi.	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.
Days.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
4	90.9	9.1	......	......	......	......	......	......	99.9	0.1	99.9	0.1	......	......
8	......	......	......	......	......	......	......	......	90.9	9.1	99	1	......	......
11	90.9	9.1	......	......	......	......	99	1	......	......	99.9	.1	......	......
14	......	......	99	1	90.9	9.1	......	......	99.99	.01	99.9	.1	99.99	0.01
22	50	50	......	......	......	......	9.1	90.9	90.9	9.1	99.9	.1	99.9	.1
30	50	50	99	1	......	......	50	50	......	......	......	......	......	......
37	......	......	50	50	......	......	99	1	90.9	9.1	90.9	9.1	90.9	9.1
45	50	50	......	......	......	......	9.1	90.9	50	50	90.9	9.1	99.9	.1
56	......	......	90.9	9.1	50	50	99	1	50	50	50	50	90.9	9.1
77	......	......	99	1	50	50	99	1	......	......	90.9	9.1	99	1
86	9.1	90.9	......	......	......	......	50	50	50	50	50	50	90.9	9.1
100	......	......	90.9	9.1	......	......	50	50	50	50	90.9	9.1	90.9	9.1
113	......	......	......	......	......	......	50	50	90.9	9.1	50	50	90.9	9.1
124	......	......	90.9	9.1	9.1	90.9	50	50	90.9	9.1	90.9	9.1	99	1
143	50	50	90.9	9.1	9.1	90.9	1	99	90.9	9.1	50	50	99	1
155	......	......	......	......	......	......	......	......	50	50	90.9	9.1	50	50
165	......	......	1	99	1	99	1	99	50	50	50	50	1	99
176	50	50	......	......	......	......	1	99	......	......	......	......	......	......
187	......	......	50	50	99	......	50	50	1	99	1	99	1	99
208	......	......	.1	99.9	1	99	......	......	......	......	......	......	......	......

Since some of the lactic bacilli develop on lactose agar plates, it was thought that if all of the colonies on a certain portion of each plate were inoculated into milk one should obtain information concerning the sequence of development of the different groups of lactic bacteria in the cheese and also concerning the ratio existing between them.

For this purpose an area showing well-isolated colonies has been circumscribed, and every colony within the area has been inoculated into milk. It has been inferred that all tubes that curdled within 48 hours at 37° C. contained *Bacterium lactis acidi*, while those that curdled between the second and tenth day contained the lactic bacilli. Enough control work was done to show that this method of differentiation is sufficiently accurate for the purpose in hand. The tubes that did not curdle in 10 days were examined microscopically to determine the organism present.

Six cheeses have been thus examined at frequent intervals during the period of ripening. The data are given in Table 18. It will be noted that the results are confirmatory of those obtained by the dilution method in milk, although not so striking, since many of the lactic bacilli do not develop on the plate cultures. The period at which the lactic bacilli appear is later than in the previous examinations (Table 16), which demonstrated their presence in considerable numbers within the first week of the ripening period. The previous examinations were made with dilution cultures in milk. In such the lactic bacilli may make themselves evident when they are present in very small numbers as compared with the *Bacterium lactis acidi.* With the plate-culture method, unless they are present in considerable numbers, their presence in the cheese is not likely to be detected. This error in the method has been previously pointed out. In the plate cultures they are likely to be missed unless they are present in a ratio of 1 to 10 of *Bacterium lactis acidi.*

The same cheeses have also been examined by the dilution method in milk. The results are given in Table 19. It will be seen that they are confirmatory of the previous analyses.

The great delicacy of the dilution method as a means of detecting the lactic bacilli in the presence of *Bacterium lactis acidi* is shown in the results given in Table 19. On the examination of cheese 308C at two days the percentage of *Bacterium lactis acidi* is given as 99.9999 and that of lactic bacilli as 0.0001. By this is meant that *Bacterium lactis acidi* was detected in dilutions approximately one million times greater than the lactic bacilli. For example, the acidity of the flask inoculated with one ten-thousandth gram of cheese was 1.64 per cent, thus indicating the presence of lactic bacilli, while the flask inoculated with one ten-billionth gram of the cheese had an acidity of 0.87 per cent, indicating *Bacterium lactis acidi.*

TABLE 18.—*The relative proportions of Bacterium lactis acidi and lactic bacilli in cheese as determined by plating on lactose agar.*

Age.	Cheese No. 307C.		Cheese No. 308C.		Cheese No. 309C.		Cheese No. 310C.		Cheese No. 311C.		Cheese No. 312C.	
	Bact. lactis acidi.	Lactic bacilli.	*Bact. lactis acidi.*	Lactic bacilli.	*Bact. lactis acidi.*	Lactic bacilli.	*Bact. lactis acidi.*	Lactic bacilli.	*Bact. lactis acidi.*	Lactic bacilli.	*Bact. lactis acidi.*	Lactic bacilli.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Milk before rennet was added	100	0	100	0	100	0	100	0	100	0	100	0
When put in press	100	0	100	0	100	0	100	0	100	0	100	0
When taken from press	100	0	100	0	100	0	100	0	100	0	100	0
2 days	100	0	100	0	100	0	......	......	100	0	100	0
3 days	100	0	100	0	......	......	......	......	100	0	......	......
4 days	100	0	86	14	90	10	100	0	100	0	......	......
5 days	100	0	......	......	100	0	100	0	......	......	......	......
6 days	......	......	100	0	......	......	......	......	......	......	......	......
7 days	100	0	100	0	100	0	100	0	100	0	......	......
9 days	100	0	86	14	100	0	100	0	100	0	......	......
11 days	100	0	90	10	100	0	......	......	......	......	100	0
14 days	100	0	100	0	90	10	100	0	100	0	86	14
18 days	100	0	80	20	100	0	33	.66	90	10	......	......
21 days	100	0	100	0	100	0	......	......	......	......	......	......
22 days	......	......	......	......	70	30	100	0	......	......	......	......
28 days	100	0	86	14	......	......	......	......	90	10	0	100
33 days	......	......	......	......	......	......	......	......	......	......	......	......
35 days	100	0	......	......	......	......	......	......	......	......	......	......
42 days	100	0	......	......	89	11	......	......	......	......	......	......
49 days	100	0	29	71	......	......	......	......	......	......	......	......
56 days	90	10	40	60	71	29	......	......	......	......	......	......
64 days	90	10	......	......	......	......	......	......	......	......	......	......

TABLE 19.—*The ratio between the numbers of Bacterium lactis acidi and the lactic bacilli at different stages in the ripening of Cheddar cheese, as determined by milk-dilution method.*

Age.	Cheese No. 307C.		Cheese No. 308C.		Cheese No. 309C.		Cheese No. 310C.		Cheese No. 311C.		Cheese No. 312C.	
	Bact. lactis acidi.	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.	*Bact. lactis acidi.*	Acid-producing bacilli.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Milk before rennet was added	......	......	......	......	99.99	0.01	......	......	99	1	99	1
Just before put in press	......	......	99.999	.001	99.9	.1	......	......	99.99	.01	......	......
When taken from press	99.99	0.01	99.99	.01	99.9	.1	......	......	......	......	99	1
2 days	99.99	.01	99.9999	.0001	99	1	99.9	0.1	99	1	99	1
3 days	99.9	.1	99	1	......	......	50	50	90.9	9.1	......	......
4 days	99.99	.01	99.9	.1	99.9	.1	99	1	99.99	.01	99	1
5 days	99.99	.01	......	......	99	1	99.99	.01	......	......	......	......
6 days	......	......	90.9	9.1	99.9	.1	......	......	......	......	99.9	.1
7 days	90.9	9.1	90.9	9.1	99	1	99.9	.1	90.9	9.1	90.9	9.1
9 days	50	50	90.9	9.1	50	50	99	1	99	1	......	......
11 days	99	1	50	50	50	50	......	......	......	......	90.9	9.1
14 days	99	1	90.9	9.1	90.9	9.1	90.9	9.1	50	50	......	......
18 days	50	50	50	50	50	50	......	......	......	......	......	......
21 days	90.9	9.1	99	1	90.9	9.1	......	......	......	......	......	......
28 days	50	50	90.9	9.1	50	50	......	......	......	......	......	......
33 days	......	......	......	......	50	50	......	......	......	......	......	......
35 days	50	50	50	50	......	......	......	......	......	......	......	......
42 days	50	50	99	1	90.9	9.1	......	......	......	......	......	......

It must not be inferred that the figures given in the tables representing the results obtained by the dilution method indicate the exact number of the different groups of lactic organisms or the exact ratio existing between them. The sudden increase or decrease of the ratio is due to the inherent errors of the dilution method. It would be an endless task to show by this method, or any other, in fact, the exact proportion between the different types of organisms in the cheese at various stages in the ripening period.

From the data presented there would seem to remain no doubt that the lactic bacilli develop later than the *Bacterium lactis acidi* group, making their appearance within a week or 10 days after the cheese is made, gradually increasing in numbers and probably attaining their maximum during the first month and then gradually decreasing in numbers. The number found per gram of the cheese ranges from a few million to one billion. Usually they do not attain such great numbers as do the ordinary lactic bacteria. Again, their numbers may equal the lactic bacteria, as in cheese No. 1, Table 16.

DETERMINATIONS BY MICROSCOPIC EXAMINATION OF THE CHEESE.

It was also thought that the gradually changing flora should manifest itself in the appearance of microscopic preparations made from the cheese. At the various periods of sampling smear preparations were made from the emulsions and stained with Gram-Weigert's stain as described on page 32.

The preparations show in a general way the same change in flora as has already been made evident by the analyses presented. It is not to be expected that the microscopic examination would give results as striking as the cultural, since the lätter measures the living cells, the former only those cells that have not lost their staining properties.

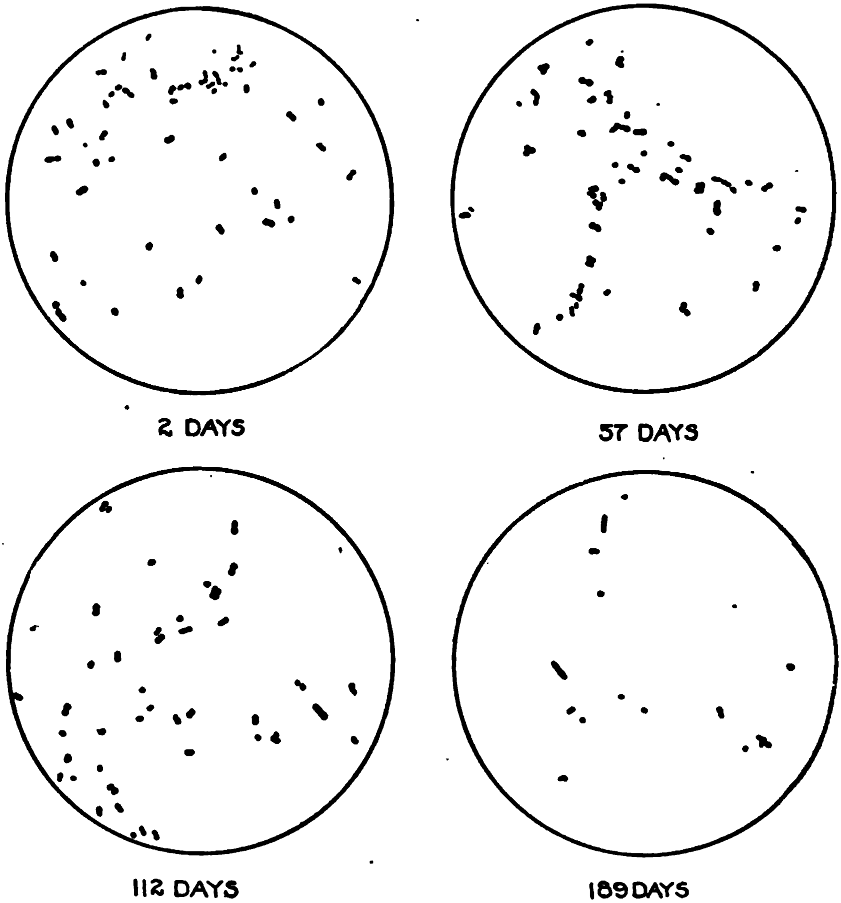
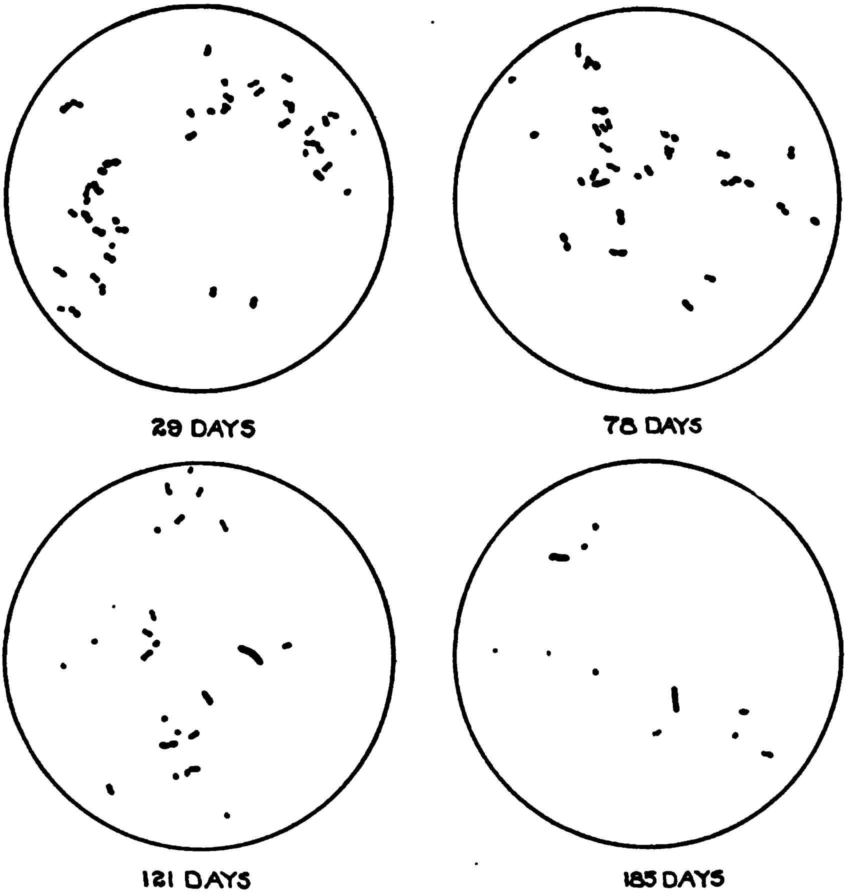


FIG. 3.—Typical microscopic fields from cheese No. 54 at different stages in the ripening process. (Camera lucida drawings.)

Figures 3 and 4 have been prepared from camera-lucida drawings of typical microscopical fields of several slides made from 2 cheeses. The results of the cultural examination have been presented in Tables 15 and 16. Figure 3 shows that at 2 and 57 days the organisms are almost, if not wholly, of *Bacterium lactis acidi* group; at 112 days there is a preponderance of *Bacterium lactis acidi* and a few lactic bacilli, while at 189 days but few *Bacterium lactis acidi* cells remain, the lactic bacilli having become more evident. Figure 4 indicates likewise that at 29 and 78 days the organisms are wholly of the *Bacterium lactis acidi* group, while at 121 and 185 days a decrease is seen in *Bacterium lactis acidi* and an increase in lactic bacilli. It will be noted that rod-shaped organisms do not appear nearly as soon as would be indicated by the cultural analyses, but that they do at last appear, especially when the cells of the lactic bacteria have greatly decreased in numbers. This may again be taken as evidence that the lactic bacilli develop subsequent to the *Bacterium lactis acidi* group and that they tend to disappear less rapidly.



29 DAYS

78 DAYS

121 DAYS

185 DAYS

FIG. 4.—Typical microscopic fields from cheese No. 91 at different periods in the ripening process. (Camera lucida drawings.)

DISAPPEARANCE OF BACTERIAL CELLS IN CHEESE.

The drawings presented in figures 3 and 4 are evidence of the gradual disappearance and disintegration of the bacterial cells in cheese. It is a well-known fact that the enzyms elaborated by bacteria in pure cultures continue to act long after the death of the cells. There are many reasons for believing that there is no enzym action until cell disintegration begins. It has been previously shown that the *Bacterium lactis acidi* group of bacteria elaborate enzyms that are able to increase the acidity of milk. As previously indicated, it may be surmised that still other types of enzyms are formed by this group of bacteria. The direct influence of the immense number of acid-forming bacteria, amounting to billions per gram, must be of great importance in cheese ripening; the indirect action through their enzyms may be still greater.

It is certainly true that in normal Cheddar cheese the period of development of the ordinary lactic bacteria—the organisms which heretofore have been believed to be the only ones of importance in cheese because of their constant presence in great numbers—is followed by the development of another group of organisms, which, while they ferment milk sugar, producing lactic acid, must have some other source of carbon in cheese on account of the total disappearance of the sugar before their maximum period of development. The influence of the first group has been pointed out early in this paper. The rôle of the second group can not at this time be determined, but because of their constant presence in numbers, approximating if not equaling those of the first group, their influence on the ripening of the cheese can not be a minor one.

DETAILED STUDY OF LACTIC BACILLI.

The work of Von Freudenreich and numerous later investigators indicates that the lactic bacilli represent a group with certain common characteristics, such as morphology, optimum temperature for growth, and to some extent in the production of compounds from the sugar fermented. In all fields of bacteriology it is difficult at the present time to draw the boundary lines of any group of bacteria. The placing of the lactic bacilli found in cheese in a single group may be incorrect, but because of the fact that all the cultures studied have certain characters in common, it seems best to discuss them as a single group, although more detailed study might divide them into a number of groups. A comparative study has been made of 20 pure cultures isolated in the course of the work. The main facts of this study are here presented. All the cultures were isolated from cheese with the exception of No. 160, which was obtained from milk. Cultures 58A and 58B represent different colonies from plates made to insure the purity of the cultures to be used in the detailed study. The differences noted in the study of these two cultures originally from the same culture illustrate the differences one may expect to obtain in cultural work.

The action of the different cultures in milk is given in Table 20, in which they have been arranged according to the degree of acidity produced in milk.

ACIDITY PRODUCED.

It will be noted from the data in Table 20 that both the rate of acid development, and hence the time required to curdle milk, as well as the maximum amount of acid produced, varies widely, the acidity varying from 0.91 per cent to 2.31 per cent. The acidity produced by each culture increased after the tenth day. Since the flasks were protected by tin-foil caps, this increase can not have been due to evaporation.

White and Avery,[1] in studying cultures from fermented milks, noted the same differences in acid production. They established two groups, one producing an acidity in milk of about 1 per cent, the other of 3 per cent, in 10 days. Such a division of the cultures studied could not be made.

Rogers[2] states that a typical culture of the lactic bacilli from fermented milk produces nearly 3 per cent of acid in three days at 37° C. Von Freudenreich and Thöni[3] studied cultures from Emmental cheese that produced from 0.2 to 1.26 per cent of acid in whey to which peptone had been added.

Out of the several hundred titrations made of milk inoculated with cheese emulsions but 15 showed an acidity above 2 per cent. When raw milk is incubated at 37° C., the acidity will often, if not in the majority of cases, exceed 2 per cent and at times may reach 3.5 to 4 per cent. It would thus seem that certain lactic bacilli present in milk do not find favorable conditions for development in Cheddar cheese.

FORMS OF LACTIC ACID PRODUCED.

A number of investigators have determined the rotary power of the lactic acid formed by the lactic bacilli. Bertrand and Weisweiller[4] concluded that the acid was a mixture of the levo and dextro forms, with a slight predominance of the latter.

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[1] White, Benjamin, and Avery, Oswald T. Observations on certain lactic acid bacteria of the so-called Bulgaricus type. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, Abteilung 2, vol. 25, No. 5/9, pp. 161–178. Jena, Nov. 30, 1909.

[2] Rogers, L. A. Fermented milks. United States Department of Agriculture, Bureau of Animal Industry, Twenty-sixth Annual Report (1909), pp. 133–161. Washington, 1911. Reprinted as Bureau of Animal Industry Circular 171, Washington, 1911.

[3] Von Freudenreich, Edward, and Thöni, J. Sur l'action de différents ferments lactiques sur la maturation du fromage. Revue Générale du Lait, vol 4, No. 8, pp. 169–181, Jan. 30; No. 9, pp. 200–209, Feb. 15; No. 10, pp. 225–232, Feb. 28; No. 11, pp. 247–259, Mar. 15. Lierre, 1905.

[4] Bertrand, Gabriel, and Weisweiller, Gustav. Action du ferment bulgare sur le lait. Annales de Institut Pasteur, vol. 20, No. 12, pp. 977–990. Paris, Dec. 25, 1906.

TABLE 20.—*Action of lactic bacilli in milk.*

Culture No.	Acidity produced in milk.		Rotation of acid.	Time of curdling.	Culture No.	Acidity produced in milk.		Rotation of acid.	Time of curdling.
	10 days.	45 days.				10 days.	45 days.		
	Per ct.	*Per ct.*		*Days.*		*Per ct.*	*Per ct.*		*Days.*
5	0.324	0.91		11	116.2	1.2	1.44	Inactive	
152	.643	1.12	Inactive		92	1.24	1.4		4
52	.68	1.05		9	160	1.37	1.6	Dextro	4
165.1	.69	1.10			165	1.41	1.57		4
163		1.26		9	113	1.57	1.88	Dextro	4
58A	.89	1.38	Inactive+levo		71	1.6	1.75		4
58B	.86	1.21	do.		91	1.68			4
128	.89	1.2			85	1.73	1.89	Dextro+inactive	4
116	.81	1.36	Inactive	4	116.1	1.75	1.96		
120	1.02		do.		96	1.89	2.31		3
104	1.17	1.46	Dextro+inactive	4					

Heinemann and Hefferan[1] report the formation of an inactive acid, while White and Avery[2] found that the organisms that produced a large amount of acid, 3 per cent, formed an inactive acid. whereas the cultures that formed acid slowly and in smaller amounts showed a levo-rotary power at the end of 24 hours, but in older cultures there were approximately equal amounts of levo and of inactive acids.

The rotary power of 9 of the cultures studied was determined by Dr. J. M. Currie. Four of these produced inactive acid; 1 produced inactive and levo acid, with a predominance of the inactive form; 2 produced a mixture of dextro and inactive acids, with a predominance of the dextro-rotatory form; and the remaining 2 produced pure dextro acid. One culture isolated from milk, of which no other study was made, produced pure levo acid. With 11 cultures isolated from other sources than milk or cheese, only the pure dextro or pure inactive acids were found.

This type of organism, then, can produce inactive acid, or active acid of either modification, or a mixture of the inactive acid with either of the active acids. All of these forms were found in cultures isolated from Cheddar cheese, with the exception of the pure levo acid.

TYPE OF CURD PRODUCED.

In most of the more active cultures the reduction of litmus and the return of color proceeded in exactly the same manner as in a litmus-milk culture of *Bacterium lactis acidi.* On the other hand, curdling took place with only a slight or partial reduction of the litmus in some cultures.

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[1] Heinemann, P. G., and Hefferan, Mary. A study of Bacillus Bulgaricus. Journal of Infectious Diseases, vol 6, No. 3, pp. 304–318. Chicago, June 12, 1909.

[2] White, Benjamin, and Avery, Oswald T. Observations on certain lactic acid bacteria of the so-called Bulgaricus type. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, Abteilung 2, vol. 25, No. 5/9, pp. 161–178. Jena, Nov. 30, 1909.

There was a slight gas formation in most of the cultures, evidence of which was found in the slight furrows or tiny holes which sometimes appeared in the curd. These gas holes were, however, not always found in curds from the same culture. Although most of the organisms grew in lactose-agar shake cultures, no gas formation was noted in any case.

FERMENTATION OF SUGARS.

Sixteen of the cultures were tested as to their power to ferment sugars. The cultures were incubated eight days at 37° C. The test for growth and fermentation of the sugar was the reddening of litmus paper. The results are given in Table 21. All of the strains tested except one, No. 128, grew in glucose bouillon. Many of the strains made no growth or only a feeble growth (indicated by the sign ±) in maltose and sucrose bouillon, although all except No. 128 grew in one or the other, or both, of these sugars.

TABLE 21.—*Growth of lactic bacilli in culture media.*

Culture No.	Growth in sugar bouillon.			Growth on lactose agar.	Growth on ordinary gelatin.	Culture No.	Growth in sugar bouillon.			Growth on lactose agar.	Growth on ordinary gelatin.
	Glucose.	Maltose.	Sucrose.				Glucose.	Maltose.	Sucrose.		
5	....	....	....	+	−	116.2	+	±	+	+	−
152	+	+	+	+	+	92	....	....	....	+	−
52	+	....	−	+	+	160	+	−	±	+	−
165.1	+	+	+	±	−	165	+	+	+	+	−
163	....	....	....	+	−	113	+	+	+	+	−
58A	+	+	±	+	+	71	+	+	±	+	−
58B	+	+	−	+	+	91	+	+	+	+	−
128	−	−	−	−	−	85	+	+	+	+	+
116	+	+	−	+	+	116.1	+	+	+	+	−
120	+	−	+	+	+	96	....	....	....	+	−
104	+	+	+	±	....						

± indicates feeble growth.

FORM OF COLONIES.

The growth upon lactose agar and ordinary gelatin was determined in plate cultures on the same media that was used for the bacteriological analysis of cheese. Growth was obtained in lactose-agar plate cultures from every strain except No. 128. There was a good growth in most of the cultures, although with some only a few colonies developed. When the plates were incubated for several days the colonies continued to increase in size, sometimes attaining a diameter of 1 mm. The surface colonies are round and the deep colonies have the common flattened elliptical form. They can not be distinguished from the colonies of *Bacterium lactis acidi.* This is probably one reason why previous investigators have failed to find this type of organism in Cheddar cheese.

Growth upon plates of ordinary gelatin was obtained from 8 of the cultures. This, however, was not constant for some strains which developed from one inoculation failed to grow from another inoculation. The variable growth of this type of organism in plate cultures can account for some of the inconsistent results obtained in the quantitative analysis of cheese by means of lactose-agar and gelatin plates.

The readiness with which some of these cultures of lactic bacilli isolated from cheese grow upon ordinary media is rather surprising, in view of what has been stated by many authors concerning this property. One of the characteristics generally given for this group of organisms is their meager growth upon ordinary media. The five cultures studied by Von Freudenreich failed to grow on ordinary gelatin or on gelatin to which an extract of cheese had been added. Cohendy[1] and Löhnis[2] found these organisms hard to cultivate because of their reluctance to grow upon the ordinary nutrient media. White and Avery state that when freshly isolated from their natural environment—milk—they do not develop on any of the usual nutrient media, even though sugar be present. Heineman and Hefferan, on the other hand, state that they grow well in milk, in media prepared from milk, or if glucose is added to the ordinary media. All of the cultures studied were isolated by means of lactose-agar plates with the exception of No. 128, which was obtained in pure culture in the dilution cultures in milk.

THERMAL DEATH POINT.

The resistance of the cultures to heat was determined on 3-day-old milk cultures which had been diluted and shaken with water and then drawn into sterile capillary tubes. The tubes were held for 30 seconds in water at various temperatures. Most of the cultures were killed at some temperature between 62° and 67° C. Two cultures were killed between 60° and 62.5° C., and two cultures were killed at about 70° C.

MORPHOLOGY.

The bacilli are nonmotile and do not bear spores. In a single microscopic field of a slide prepared from a pure culture the organisms may vary in length from 2.5 microns to 20 or 30 microns or more. Sometimes the filaments are very long. In one of the pure cultures a filament was found 75 microns in length. In one of the mixed cultures inoculated from cheese there was found a filament which was about 960 microns in length, extending four times across the field of the microscope. The filaments are apparently made up of a number of individual cells which for some reason do not show the cell divisions, for frequently chains of rods are found instead of filaments. Occasionally in a mixed culture from a cheese inoculation filaments were found very much curled, or curled at one end, but attempts to isolate a culture which would regularly produce curled filaments always resulted in securing a culture with the usual morphology. No curled filaments were ever observed in pure cultures. The width of the cells in a pure culture seems to be fairly constant; in some cultures the individual cells are all slender, in other cultures they are all comparatively thick. In different cultures the width varies from 0.4 to 1.3 microns. No branching forms have ever been observed.

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[1] Cohendy, Michel. Essais d'acclimation microbienne persistante dans la cavité intestinale. Comptes Rendus Hebdomadaires des Séances de la Société de Biologie, vol. 60 (année 58, tome 1), No. 7, pp. 364–366. Paris, Feb. 23, 1906.

[2] Löhnis, F. Versuch einer Gruppierung der Milchsäurebakterien. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, Abteilung 2, vol. 18, No. 4/6, pp. 97–149. Jena, Mar. 14, 1907.

When stained with methylene blue the ends of the cells may take the stain much more deeply than the remainder of the cell, or the deeply stained spots may be scattered irregularly in the filament. Occasionally the deeply stained spots appear as tiny nodules on the rod. These characteristic staining properties are less frequently exhibited when stained by the Gram-Weigert method. In a weakened culture filaments are sometimes found with some of the cells Gram positive, some of them Gram negative, and other cells taking the stain partially.

Although there is such a wide difference between the cultures in regard to the production of acidity in milk, the other characteristics do not differentiate a culture producing a low acidity from one which produces a high acidity. The morphology, however, seems to bear some relation to the acidity produced, those producing a high acidity being more slender than those producing a low acidity.

CONDITIONS FOR GROWTH IN CHEESE.

It has been pointed out that in their development in cheese the lactic bacilli follow the *Bacterium lactis acidi* group, and that the greater part of the growth must occur after the disappearance of the sugar. Since lactic acid is the principal by-product of the fermentation of the sugar, it might seem probable that the lactic bacilli would make use of this as a source of carbon and of energy. Analyses of cheese show no decrease in lactic acid[1] at the period of development of the lactic bacilli. This indicates that this group of bacteria does not act on the lactic acid.

The action of the pepsin of the rennet extract activated by the lactic acid results in the formation of peptones from the paracasein. The favorable effect of peptone on the lactic bacilli is shown in the following experiment. Small flasks containing 100 c. c. of sterile milk were inoculated with cultures Nos. 5, 92, 91, and 96. To one flask of each set there had been added before sterilization 0.5 gram of peptone, and to another flask 1 gram. The control flask received no peptone. In Table 22 the acidity at 10 days and 45 days is given. The results show clearly that milk to which peptone has been added is a better medium than plain milk for the growth of this group of organisms. This was especially true in the case of culture No. 5, which usually curdled milk in about 11 days, but which curdled the milk to which peptone had been added in two days—more rapidly than the most active cultures curdle plain milk. The time of curdling was shortened by the peptone 3 days in the case of culture No. 91. and 1 day in cultures Nos. 92 and 96. In every case the final acidity at 42 days was considerably greater than in plain milk, and in every case but one (culture No. 91, at 42 days) there was a greater development of acidity in the milk containing 1 gram than in the milk containing 0.5 gram of peptone.

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[1] Suzuki, S. K.; Hastings, E. G.; and Hart, E. B. The production of volatile fatty acids and esters in Cheddar cheese and their relation to the development of flavor. Wisconsin Agricultural Experiment Station, Research Bulletin 11. Madison, June, 1910. See p. 135.

Incidentally, this experiment shows that the cessation of growth in milk when a certain percentage of acidity is reached, which is a fairly constant percentage for each particular culture, is not brought about by the antiseptic action of the acid, but by a lack of suitable nitrogenous food.

TABLE 22.—*Percentage of acidity produced by lactic bacilli in milk to which peptone has been added.*

Culture No.	Acidity in 10 days.			Acidity in 42 days.		
	Plain milk.	Milk with 0.5 gram peptone.	Milk with 1 gram peptone.	Plain milk.	Milk with 0.5 gram peptone.	Milk with 1 gram peptone.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
5	0.324	1.19	1.32	0.855	1.35	2.34
92	1.24	1.4	1.58	1.4	1.56	1.77
91	1.68	1.9	2.1	....	2.42	2.29
96	1.58	1.87	1.96	1.93	2.13	2.25

The action of the enzyms present in the cheese curd brings about an increasing amount of soluble nitrogenous compounds so that after one month of ripening about 18 per cent of the total nitrogen is in the form of water-soluble compounds.[1] This action must render the curd a medium favorable to the growth of the lactic bacilli, and particularly to those strains similar to culture No. 5, which grow so slowly in milk, or fail to grow therein, as frequently happens.

The dependence of this group of organisms upon enzyms from other sources is shown by growing them together with other types of bacteria. Marshall and Farrand[1] have shown that when *Bacterium lactis acidi* grows in milk together with certain other organisms there is an associative action which accelerates the production of acid and the proliferation of cells. This quickening action was found to occur in the case of 57 per cent of the cultures grown in association with *Bacterium lactis acidi*. A similar action, but more pronounced, takes place when the lactic bacilli grow in milk together with certain other types of organisms.

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[1] Van Slyke, L. L., and Hart, E. B. Conditions affecting chemical changes in cheese-ripening. New York Agricultural Experiment Station, Bulletin 236. Geneva, July, 1903. See p. 150.

Suspensions in water were made of a 48-hour milk culture of the lactic bacillus No. 104 and also of 48-hour glucose bouillon cultures of two different strains of liquefying bacteria, which were isolated from poor cheese. This particular type of organism has not been found in good cheese. Small flasks of milk were inoculated with various dilutions of these suspensions, as given in Table 23. Since the results from the two experiments were similar, the figures for only one of them are given.

TABLE 23.—*Associative action of lactic bacilli and a liquefying organism.*

Flask No.	Inoculation with liquefier.	Inoculation with lactic bacilli.	Acidity in 2 days.	Acidity in 3 days.	Acidity in 7 days.
			Per cent.	*Per cent.*	*Per cent.*
I	1 : 1,000	No inoculation	0.17	0.17	0.34
II	1 : 1,000	1:10,000,000	.18	.59	1.44
III	1 : 1,000	1:100,000	.26	.85	1.53
IV	1 : 1,000	1:1,000	.40	.96	1.44
V	1 : 100,000	1:1,000	.36	.91	1.42
VI	1 : 10,000,000	1:1,000	.42	.99	....
VII	No inoculation	1:1,000	.31	.62	1.36

It will be seen that in 2 days the production of acidity was accelerated in the cultures which received an inoculation of the liquefier. This was more pronounced in 3 days, but less pronounced in 7 days, when the flask which received no inoculation of the liquefier showed only a small amount of acidity less than the flasks inoculated with both cultures.

Other experiments were made with cultures of coccus forms isolated from cheese. The liquefying action of these was not pronounced, yet they exerted a stimulating effect on the lactic bacilli. Reference to the coccus forms found in cheese will be made later.

SOLVENT EFFECT ON MILK PROTEINS.

Von Freudenreich was the first to demonstrate the fact that lactic bacilli exert a digestive effect. The same action[2] was shown for cultures isolated from milk and has also been demonstrated by more recent investigators.

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[1] Marshall, Charles E., and Farrand, Bell. Bacterial associations in the souring of milk. Michigan Agricultural Experiment Station, Special Bulletin 42. East Lansing, Mar., 1908.

[2] Hastings, E. G., Hammer, B. W., and Hoffman, C. Studies on the bacterial and leucocyte content of milk. Wisconsin Agricultural Experiment Station, Research Bulletin 6. Madison, June, 1909. See p. 202.

The solvent effect of 8 of the cultures studied has been determined by the analyses of milk cultures after 3 months' incubation. The results are given in Table 24.

TABLE 24.—*The solvent effect of lactic bacilli on milk proteins.*

Culture.	Soluble N. in 100 c. c. of milk.	Increase in soluble N in 100 c. c. of milk.	
	Gram.	*Gram.*	*Per cent.*
Sterile milk	0.064	.....	....
116	.072	0.008	12.5
113	.076	.012	18.7
152	.080	.016	25.0
120	.081	.017	26.5
116.1	.090	.026	40.6
116.2	.092	.028	43.7
71	.096	.032	50.0
52	.104	.040	62.5

COCCUS FORMS IN CHEDDAR CHEESE.

Several investigators have mentioned coccus forms in relation to cheese ripening. Von Freudenreich and Thöni[1] found regularly a liquefying micrococcus in quite large numbers in fresh Emmental cheese. They made a number of experimental cheeses, using this type of organism alone as a starter or together with lactic starters. They concluded that when present in too great numbers the liquefying micrococci produced bitterness, but that they disappeared quite rapidly in practical cheesemaking. Gorini[2] isolated a coccus with the property of peptonizing casein in an acid medium from Grana, Emmental, and Edam cheese. He found these forms not only in the fresh cheese, but in cheese several months old. He thought that they were not all of the same type, and he related them to the normal flora of the udder. In a more recent publication[3] Gorini states that later investigations have confirmed his opinion that acid-producing peptonizing ferments are important in the ripening of cooked cheeses and that the fundamental flora of Grana and other cooked cheeses is composed of two types of bacteria; (1) lactic acid bacteria, and (2) acid-producing, peptonizing ferments. In the latter class he includes bacillus forms with those properties and divers types of cocci.

No reference to coccus forms having been found in considerable numbers has been made in the literature on Cheddar cheese. Harding and Prucha[1] report the presence of acid-producing, liquefying coccus forms in 9 out of 10 cheeses studied. They state that these forms occurred sufficiently often to suggest that they might play some part in the ripening changes, but that they made little headway in the cheese, and their number, as compared to the total germ content of the cheese, was relatively insignificant.

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[1] Von Freudenreich, Edward, and Thöni, J. Sur les bactéries du lait normal et leurs rapports avec la maturation des fromages. Revue Générale du Lait, vol. 2, No. 11, pp. 241–247, Mar. 15; No. 12, pp. 271–280, Mar. 30, Lierre, 1903.

[2] Gorini, C. Sur la présence de bactéries productrices d'acidité et de présure dans les fromages en maturation. Rue Générale du Lait, vol. 3, No. 22, pp. 505–510. Lierre, Aug. 31, 1904.

[3] Gorini, C. Studi sulla fabbricazione dei fromaggi Grana, ecc. Italy-Ministero di Agricoltura, Industriae Commercia. Bollettino. Anno 9, vol. 1, ser. C, No. 6, pp. 9–17. Rome, June, 1910.

Coccus forms which produce a small amount of acidity were occasionally found to be the predominating type of organism in the cheeses studied, as shown by the milk cultures from high dilutions of the cheese. Unfortunately, with the dilution method of analysis this type can be differentiated only when it predominates, for if it occurs in a culture with the other cheese organisms it can not be distinguished with certainty from the *Bacterium lactis acidi* type in a microscopic preparation, and the titration of the milk gives no information, since its production of acidity is less than either the lactic bacilli or *Bacterium lactis acidi.* However, this type has been found to predominate at some time or other in 11 of the 13 cheeses examined by this method.

In 4 of the 11 cheeses the maximum number of coccus forms found was 100,000,000 per gram, in 4 other cheeses 1,000,000,000, and in the 3 remaining 10,000,000,000 per gram. The time at which they predominated varied from the 14th to the 161st day. This would indicate that they increase early in the ripening period and maintain such numbers for a considerable period. The coccus forms have more or less of a liquefying action on gelatin; a few show a decided action, some none at all, while the majority produce a minute depression in the gelatin around the colony. Their action is not comparable with that of those organisms usually classed as liquefying bacteria. They produce small crystals in milk that enables one to differentiate them from *Bacterium lactis acidi.* The nature of these crystals has not yet been determined.

The various cultures produced acidities in milk varying from 0.35 to 0.80 per cent.

As has been previously mentioned, all of the colonies from a circumscribed area on the lactose-agar plates prepared from the cheeses last examined were inoculated into milk. The formation of the crystals was used to distinguish the coccus forms. In some cheeses, especially those with a low germ content, the cocci have made up from 10 to 40 per cent of the bacteria as determined by lactose-agar plate cultures. In other cheeses they have not been detected in many of the examinations made, and when found were in minor numbers.

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[1] Harding, H. A., and Prucha, M. J. The bacterial flora of Cheddar cheese. New York Agricultural Experiment Station, Technical Bulletin 8. Geneva, Dec., 1908. See p. 184.

It should be mentioned, however, that this method of detecting the various kinds of organisms in cheese is subject to considerable error, especially when certain forms are present in much smaller numbers than other forms, as is the case with the coccus forms as compared with the lactic bacteria of both groups in many of the cheeses examined. The error can be reduced by making subcultures of a greater number of colonies. By the extension of this method or by the use of some differentiating medium they may be shown to make up a considerable part of the flora of normal Cheddar cheese.

CHROMOGENIC COCCI.

The chromogenic cocci can be distinguished on the plate cultures when they are present in appreciable numbers. In a portion of the work the number of colonies of chromogens appearing on gelatin plates was determined. The results seemed to indicate a relative increase late in the ripening period. As has previously been pointed out, it is impossible to determine, in the case of any group of organisms for which no means of differentiation from other groups has been found, whether growth is taking place in cheese or not.

It is characteristic of the chromogenic cocci that they persist and possibly grow under conditions which rapidly destroy less resistant types. They are present in butter, in which food material is limited, and in which the moisture represents a saturated solution of sodium chlorid. Efforts were made to determine their number in cheese by plating on gelatin containing 3 or 4 per cent of sodium chlorid. The results were quite satisfactory as far as the chromogenic types were concerned, but since many other coccus forms did not grow thereon its use was given up.

In some cheeses very few chromogenic forms have been found, while in others of similar quality they have been present quite consistently in considerable numbers. In cheese which contained more than the usual amount of salt they made up a relatively greater proportion of the flora than in other cheese.

LIQUEFYING ORGANISMS.

Attention has been directed to those organisms that show a pronounced liquefying action on gelatin and casein. The results have been confirmatory of a statement made earlier that they can not be considered of importance in the ripening of Cheddar cheese since they are not consistently present in sufficient numbers to exert any effect.

THE SEQUENCE IN DEVELOPMENT OF BACTERIAL GROUPS IN CHEDDAR CHEESE.

In the first part of this bulletin it was stated that the normal ripening of each kind of cheeese is to be looked upon as a problem in the ecology of microorganisms, and that the only group of organisms which has been found by previous investigators in every Cheddar cheese in great numbers is the *Bacterium lactis acidi* group. The work herein reported proves that another group of bacteria, the so-called *B. bulgaricus* group, develops after the first, and that it reaches approximately equal numbers.

Each of these groups of organisms produces certain changes in the cheese mass, consuming the same class of substances and giving out the same by-products in every cheese which ripens normally. The second group takes up the work of decomposition at a certain stage of the ripening, and brings about its own peculiar changes which prepare the cheese mass for possibly still other types of organisms, and so on to the end of the ripening.

If a certain sequence of groups of microorganisms is essential for the preparation of a certain product from raw material, and if the various members of the sequence find favorable conditions for growth in the raw material, the resulting product will depend on the first member of the normal sequence developing to the necessary degree before the second appears. If the first is overwhelmed by the addition of great numbers of the second, the decomposition changes will not be normal. The presence of great numbers of organisms of the first member of the sequence will not cause a disturbance in the normal decomposition changes. Thus, in the manufacture of Cheddar cheese, cultures of *Bacterium lactis acidi* are added.

The other essential groups of microorganisms are present in the milk in small numbers, but as conditions become favorable they develop in the cheese, and a typical Cheddar cheese results.

If heavy inoculations of lactic bacilli are made in milk which contains a small number of *Bacterium lactis acidi* the normal ecological balance will be destroyed, and the result will not be a normal product. Experiments have been made along this line by the use of milk which has been pasteurized in such a manner that the result has been the great reduction of all groups of bacteria therein, but the total destruction of none. In its decomposition such milk is similar to raw milk, which contains but few bacteria. If cheese is prepared from such milk after the addition of a culture of *Bacterium lactis acidi*, it may ripen in a quite normal manner. The development of the flavor is usually slower than in a cheese made from raw milk. If to this same milk is added a culture of lactic bacilli instead of *Bacterium lactis acidi*, the ripening is not nearly so normal. The result is an increased rate of ripening and the production of an abnormal flavor.

This work also indicates that it is often useless to attempt to establish the rôle of any organism in cheese ripening by the addition of cultures to the milk to be used, since thereby the natural equilibrium is destroyed, and the results obtained indicate that the addition has injured the product, and hence the conclusion is drawn that the organism added is not only not essential, but even harmful, although the organism may be an essential factor in the decomposition changes when developing in its normal sequence.

The constant presence in large numbers is the only certain proof of the importance of an organism or group of organisms in the ripening of any cheese.

SUMMARY.

1. From the same raw materials various kinds of cheese are prepared, which differ especially in flavor. The factors that determine whether a cheese to be prepared from a given mass of milk, rennet, and salt is to be of one kind or another are to be found in the methods of the cheese maker, who is able to vary in one way or another the composition of the cheese, with the result that conditions are established that favor or retard the growth of the groups of micro-organisms, which must be the determining factors between different kinds of cheese.

2. The only group of bacteria found constantly in great numbers in Cheddar cheese by previous investigators is the *Bacterium lactis acidi* group. The functions of this group in Cheddar cheese are, through their chief by-product, lactic acid—

(*a*) To favor the curdling of milk by rennet.

(*b*) The bacteria of the milk are held in great part in the curd. Through the acid they influence the shrinking of the curd and expulsion of the whey.

(*c*) The acid so changes the nature of the curd as to cause "matting."

(*d*) The acid activates the pepsin of the rennet extract.

(*e*) The acid prevents the growth of putrefactive bacteria in the cheese.

3. It has been shown that *Bacterium lactis acidi* is able to form acid in the absence of the living cell.

4. The development of *Bacterium lactis acidi* is followed by the growth of another group of acid-forming bacteria, the *Bacillus Bulgaricus* group. They reach numbers comparable with those of the first group, reaching their maximum numbers within the first month of the ripening. Since they develop after the fermentation of the sugar, they must have some other source of carbon and of energy than milk sugar.

5. It is probable that coccus forms are constantly found in large numbers in Cheddar cheese.